# Trajectory Prediction Accuracy Report: User Request Evaluation Tool (URET)/ Center-TRACON Automation System (CTAS)

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15. Abstract

This report presents the results of an independent analysis of the accuracy of the trajectory modelers implemented in the User Request Evaluation Tool (URET) and Center-TRACON Automation System (CTAS) prototypes. These results are based on the completion of the first phase of a planned two phased effort. As originally envisioned, efforts during Phase 1 would develop a generic methodology to measure the trajectory prediction accuracy of any decision support tool (DST), which would be validated by applying it to CTAS and URET based on their currently adapted sites. In Phase 2, the methodology would be applied to URET and CTAS adapted to a common site and supplied with the same scenario. As such, the results from Phase 2 would have provided a common set of results based on the same site and scenario, allowing a comparison of the two trajectory modelers to be made, in support of research into the performance requirements for a common en route trajectory model. Due to funding cuts, this task was curtailed to the completion of Phase 1. The results from this phase do provide the FAA with an independent set of scenario-based trajectory accuracy statistics for each DST, but they cannot be used to compare the two DSTs due to the confounding site-specific factors.

A methodology was developed and CTAS and URET were measured based on one scenario each from their currently adapted sites (Fort Worth and Indianapolis, respectively). The Phase 1 study measured the spatial error between trajectory predictions versus the Host Computer System (HCS) track position reports, which were assumed to be the ground truth location of the aircraft. The spatial error consisted of horizontal and vertical errors. The horizontal error was further partitioned into two geometric components, lateral and longitudinal errors, representing the cross track and along track prediction errors. The focus of the analysis was on the overall trajectory accuracy of each DST, not on individual errors. A statistical analysis was performed on the overall accuracy of each modeler and the spatial errors have been summarized with descriptive statistics in the horizontal, lateral, longitudinal, and vertical dimension as a function of look ahead time. Inferential statistics were performed to determine whether specific factors (e.g., look ahead time, flight type, horizontal phase of flight and vertical phase of flight) had a significant effect on these performance statistics.

While the Phase 1 analysis cannot be used to compare the URET and CTAS trajectory modelers, the results do provide the FAA with an independent scenario-based set of trajectory accuracy measurements for each DST. In addition, a generic methodology has been developed that can be used to determine the performance requirements for a common en route trajectory model.


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The overall effort required to successfully accomplish this task was supported by several other members of ACT-250. In particular, Jeff Jackson of Signal Corporation supported the Oracle database system, which is a major part of the infrastructure upon which the data reduction and analysis tools reside. As system administrator in the Traffic Flow Management Laboratory, Craig Stewart of Signal Corporation provided continuous support and attention to the team's special needs, which is greatly appreciated. Richard Van Suetendael conducted a thorough technical review of the document and provided many insightful comments. Finally, special thanks go to Joan Feuerstein for her extensive help in preparing the document; without her, the timely completion of this report would not have been possible.

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# Executive Summary

In the spring of 1998, the FAA Air Traffic Management (ATM) Engineering, Research and Evaluation Branch (ACT-250) was tasked by the En Route Area Work Team lead (at the time, AUA-540), of the Interagency Air Traffic Management Integrated Product Team (IAIPT), to conduct an independent assessment of the technical accuracy of the User Request Evaluation Tool (URET) and Center TRACON Automation System (CTAS) aircraft trajectory modeling algorithms. This study was initiated under IAIPT Joint Research Project Description (JRPD) 57 in support of research into the performance requirements for a common en route trajectory model. The task was partitioned into two parts. In Phase 1, a generic methodology to measure trajectory prediction accuracy would be developed and validated by applying it to CTAS and URET at their currently adapted sites. For Phase 2 the same methodology would be applied to CTAS and URET adapted to a common site and supplied with the same scenario. Due to funding limitations in FY99, this task was curtailed to the completion of only Phase 1, which is documented in this report. As such, it provides the FAA with an independent scenario based analysis of URET and CTAS trajectory prediction accuracy but these results can not be used to compare the two modelers due to the confounding site-specific factors.

A generic methodology was developed to analyze any Decision Support Tool's (DSTs) trajectory modeling. This methodology took the point of view of an air traffic controller using the DST. That is, a Controller viewing the aircraft predicted position data on the graphical user interface of the DST would wonder how accurate the predictions were into the future, e.g., 5 minutes, 10 minutes, 20 minutes, and beyond. The Controller is not necessarily interested in the interior workings of the tool, e.g., how recently the tool made its currently valid predictions, but rather how accurate the prediction is now, and into the future. Built upon this conceptual point of view of the user, a sampling process was used to obtain the measurement data. At selected times the actual position of the aircraft was obtained from the HCS radar track data and was compared with the position of the aircraft predicted by the tool.

The results presented are based on field data collected at Fort Worth Air Route Traffic Control Center (ARTCC) in January 1999 for CTAS and in Indianapolis Air Route Traffic Control Center (ARTCC) in February 1998 for URET. Both scenarios were approximately 7 to 7.5 hours in duration and provided about 2500 flights for analysis. The analysis was performed on approximately 17,000 URET trajectories and 32,000 CTAS trajectories. The main focus of the analysis was on the overall trajectory accuracy of each DST. The spatial errors have been summarized with descriptive statistics in the horizontal, lateral, longitudinal, and vertical dimensions as a function of look ahead time. Inferential statistics were performed to determine whether specific factors (i.e., look ahead time, flight type, horizontal phase of flight, and vertical phase of flight) had a significant effect on these performance statistics. For URET, the sample means of the horizontal error as a function of look ahead time range from 1.2 to 10.2 nautical miles for zero to 30 minutes look ahead time. The sample standard deviations range from 1.1 to 10.9 nautical miles. For CTAS, the sample means of horizontal error as a function of look ahead time range from 0.3 to 10.9 nautical miles for 0 to 30 minutes look ahead time. The sample standard deviations range from 0.9 to 11.2 nautical miles. For both URET and CTAS, the average and standard deviation of the horizontal error increased as look ahead time increased. In other words, the horizontal uncertainty of the trajectory predictions analyzed in this study increased by about 10 nautical miles on average as look ahead increased from zero to 30 minutes into the future.

While the Phase 1 analysis cannot be used to compare the URET and CTAS trajectory modelers, the results do provide the FAA with an independent scenario based set of trajectory accuracy measurements for each DST. All of the data from this study is stored in a large set of Oracle database tables in the WJHTC TFM Laboratory. This data can be made available to other members of the FAA community who may wish to analyze other factors, or answer other questions of interest, related to the trajectory prediction accuracy of URET and CTAS upon formal request to ACT-250. In addition, a generic methodology has been developed for the performance measurement of a common trajectory model. In FY99, this methodology and the parsing tools developed in this study will be applied to the development of DSR Workload Scenarios to be used for URET CCLD accuracy testing. With the planned adaptation of URET and CTAS to a common site (tentatively scheduled to occur in 2001) and anticipated funding availability in FY01, ACT-250 hopes to resume work on the proposed Phase 2 study to further address the FAA's efforts to determine the feasibility of a common en route trajectory model.

# 1. Introduction

## 1.1 Purpose

This report presents the results of an independent analysis of the accuracy of the aircraft trajectory modelers implemented in the User Request Evaluation Tool (URET) and the Center-TRACON Automation System (CTAS) prototypes. This study was conducted by the Air Traffic Management (ATM) Engineering, Research and Evaluation Branch (ACT-250) at the FAA William J. Hughes Technical Center (WJHTC). Quantitative measures of the trajectory accuracy of URET and CTAS are presented in terms of the following metrics: horizontal error (longitudinal error and lateral error) and vertical error. These results are based on analyses of field data obtained from the Indianapolis and Fort Worth Air Route Traffic Control Centers (ARTCCs) where the URET and CTAS prototypes, respectively, are currently implemented; as such, while this report provides useful information on the accuracy of the individual tools, the results cannot be used to compare the performance of the trajectory modelers.

## 1.2 Background

To achieve the goals of Free Flight, broad categories of advances in ground and airborne automation are required. The FAA has sponsored the development of two ground based ATM decision support tools (DSTs) to support the en route and arrival air traffic controllers. URET, developed by MITRE/CAASD, facilitates the controller's management of en route air traffic by identifying potential air traffic conflicts. CTAS, developed by NASA Ames Research Center, supports the controller in the development of arrival sequencing plans and the assignment of aircraft to runways to optimize airport capacity. A fundamental component of both URET and CTAS is the trajectory modeler, upon which the functionality provided by these tools is based. For example, URET uses its predicted trajectories to predict conflicts; CTAS uses its predicted trajectories to calculate meter fix crossing times. Thus, the trajectory accuracy, or the deviation between the predicted trajectory and the actual path of the aircraft, has a direct effect on the overall accuracy of the tool.

The prediction accuracy of URET and CTAS is a critical issue to be addressed in planning for Free Flight Phase 1 (FFP1) and the future integration of these tools. NASA Ames Research Center and MITRE/CAASD have each created and applied performance metrics for their specific tools (Bilimoria, 1998; Brudnicki et. al., 1998). The ATM Engineering, Research and Evaluation Branch (ACT-250) at the FAA WJHTC has defined a generic set of metrics that highlight the performance of any decision support tool: trajectory accuracy, conflict prediction accuracy, prediction stability and conflict notification timeliness (WJHTC/ACT-250, 1997 and Cale et al., December 1998). Since these metrics are independent of a particular system's design choices, they provide common measures to evaluate the performance of different systems. In early 1998, ACT-250 applied the conflict prediction accuracy metrics to URET (Cale et al., April 1998). Following the completion of the URET conflict prediction accuracy assessment, ACT-250 was tasked by the Interagency ATM Integrated Product Team (IAIPT) En Route Area Work Team lead (at that time, AUA-540) to conduct an independent assessment of the technical accuracy of the CTAS and URET trajectory modeling algorithms. This report focuses on the initial application of the trajectory accuracy metrics to URET and CTAS.

## 1.3 Scope

ACT-250's original plan for the trajectory accuracy study called for a two-phased effort. During the first phase, the necessary data reduction and analysis tools would be developed and validated

by applying them to URET and CTAS based on the ARTCCs to which these DSTs were currently adapted (i.e., Indianapolis and Fort Worth). Phase Two then called for both systems to be adapted to a common ARTCC, with the trajectory accuracy study conducted based on this common data and a report issued. Toward the end of Phase One, funding was cut for ACT-250's IAIPT tasks for FY99 and ACT-250's focus shifted to the development of scenarios to be used for the FFP1 URET Core Capability Limited Deployment (CCLD) accuracy testing. Since the initial trajectory study was almost completed and many of the tools being developed were required by the scenario development task, it was decided to complete this study and provide a report even thought the results are limited to the Phase One effort. Therefore, while the results presented provide an estimation of the accuracy of the individual tools' trajectory modelers, this data can not be used to compare the two modelers because it is based on information from two different centers at different time periods with different weather characteristics.

## 1.4 Document Organization

This report is organized into five sections and three appendices. Section 2 provides a detailed description of the methodology employed to conduct the trajectory accuracy study. Sections 3 and 4 describe the scenarios, and observations and results for the URET and CTAS studies, respectively, and Section 5 provides a summary of the study. Document references and a list of acronyms are also provided. In addition, three appendices are provided: detailed descriptions of the data analyzed for each tool are provided in Appendix A, standard deviation statistical plots of results are provided in Appendix B, and additional flight observation examples are provided in Appendix C.

# 2. Trajectory Accuracy Study Methodology

The WJHTC ATM Engineering, Research and Evaluation Branch (ACT-250) has been involved in the development and application of metrics to assess various aspects of decision support tools since early 1997 (WJHTC/ACT-250, 1997; WJHTC/ACT-250, 1998; Cale et. al, April 1998; Cale et. al, December 1998). The fundamental characteristic of these metrics is their independence from any particular DST's design choices, thus providing common measures to evaluate the performance of different systems. The approach employed for this study used field data recorded at two of the ARTCCs where the URET and CTAS prototypes are currently implemented.

The effective estimation of the trajectory accuracy metrics required considerable data to be collected and analyzed. A generic set of data reduction and analysis tools was developed, building upon ACT-250's Traffic Flow Management (TFM) Laboratory's Oracle database system and tools previously developed for the URET Conflict Prediction Accuracy Study (Cale et. al., April 1998). This section describes these generic techniques as they were used in this trajectory study, and provides information on the definitions used throughout the study, the sources of data and the data processing methodology, the data processing reports that were generated, and the analysis performed. Sections 3.2 and 4.2 contain observations for URET and CTAS, respectively, that demonstrate the application of this methodology.

## 2.1 Overview

Three major process areas comprise the Trajectory Accuracy Study methodology (shown in Figure 2.1-1):

1. **Field Data Parsing** - The recorded field data, which may be provided in different formats, is parsed to extract the flight plan data, the track data, and the trajectory data into a common format. The details of this DST-specific parsing are provided in Sections 3.1 and 4.1.
2. **Flight Plan and Track Data Processing** - The software in this process area filters and characterizes the track data, placing the results in tables in the TFM Laboratory Oracle database. Details on this processing are provided in Section 2.4.
3. **Trajectory Data Processing and Trajectory Report Generation -** During these processes, the trajectory data is sampled and compared with the track data, the metrics are calculated and placed into tables in the TFM laboratory Oracle database, and reports are generated. Trajectory data sampling is necessary due to the differences in trajectory creation methods employed by URET and CTAS (i.e., CTAS computes a new trajectory every 12 seconds for every track update, while URET's trajectory creation is mainly event driven); on average, 10-12 times more trajectories were created for CTAS than for URET. Because of this, a sampling technique was designed to create equivalent sets of trajectory data for analysis. Details on this processing are provided in Section 2.5.

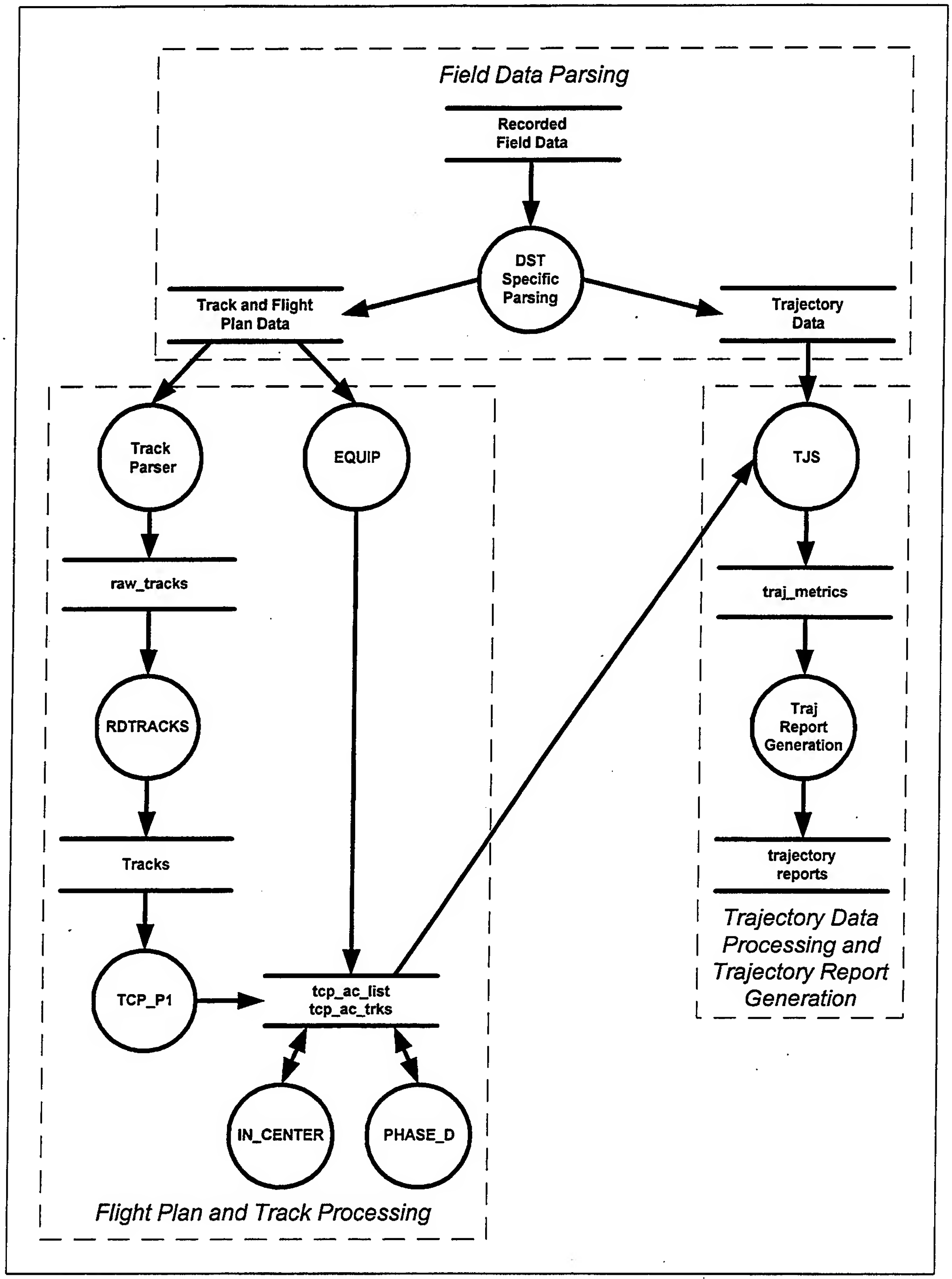


**Figure 2.1-1: Trajectory Accuracy Study Methodology Overview**

## 2.2 Definitions

This section defines the basic terms used throughout this report. These are grouped into three categories: data definitions, metrics definitions, and factor definitions.

### 2.2.1 Data Definitions

Three types of data were used as input to this study: flight plan, track, and trajectory data.

#### 2.2.1.1 Flight Plan Data

A flight plan consists of time stamped records containing information about the aircraft's flight, including: aircraft identification (ACID), computer identification number (CID), aircraft type, coordination fix, coordination time, and intended route of flight. For both URET and CTAS, the flight plan data for this study was recovered from flight plan and flight plan amendment messages output from the ARTCC Host Computer System (HCS) and recorded by the URET or CTAS interface software.

#### 2.2.1.2 Track Data

Track data represents the position of an aircraft as reported by the ARTCC HCS. An aircraft's track is represented by a sequence of four-dimensional data points, with each data point consisting of three spatial coordinates (denoted $X_i$, $Y_i$, and $Z_i$) and their associated time (denoted $T_i$,), where i refers to a particular data point. For both URET and CTAS, the track data for this study was recovered from track messages output from the ARTCC HCS and recorded by the URET or CTAS interface software.

#### 2.2.1.3 Trajectory Data

Trajectory data represents the position of an aircraft as predicted by the DST into the future. A trajectory is a sequence of four-dimensional data points, with each data point consisting of three spatial coordinates (denoted $X_i$, $Y_i$, and $Z_i$) and their associated time (denoted $T_i$,), where i refers to a particular data point. The trajectory data for this study was directly captured from the URET and CTAS trajectory modelers.

### 2.2.2 Metrics Definitions

Trajectory accuracy can be measured as the spatial difference between the predicted path of the aircraft determined by the DST and the aircraft's actual path. This difference is the slant range distance between the predicted trajectory position and the actual track position at a common time. A perfect prediction would have a slant range of zero.

For this study, trajectory accuracy was measured as the difference between the URET or CTAS predicted trajectory and the tracked position reports received from the ARTCC HCS. This slant range distance was decomposed into three orthogonal components: longitudinal error and lateral error in the horizontal plane, and vertical error perpendicular to the horizontal plane. Both the longitudinal and lateral errors are also orthogonal components of the horizontal error. The horizontal error is the slant range's projection onto the horizontal plane. These errors are actually vectors, however statistical analysis was performed only on their scalar lengths and a sign convention was used for direction, where appropriate. The details for estimating these metrics are presented in Section 2.5.1.2.

#### 2.2.2.1 Longitudinal Error

The longitudinal error represents the along track distance difference between a track and its trajectory. This error, depicted in Figure 2.2-1, lies in the horizontal plane defined by a track point

and two consecutive trajectory points. As seen in Figure 2.2-1, a positive longitudinal error indicates that at a corresponding point in time the aircraft is ahead of where the trajectory predicted it would be.

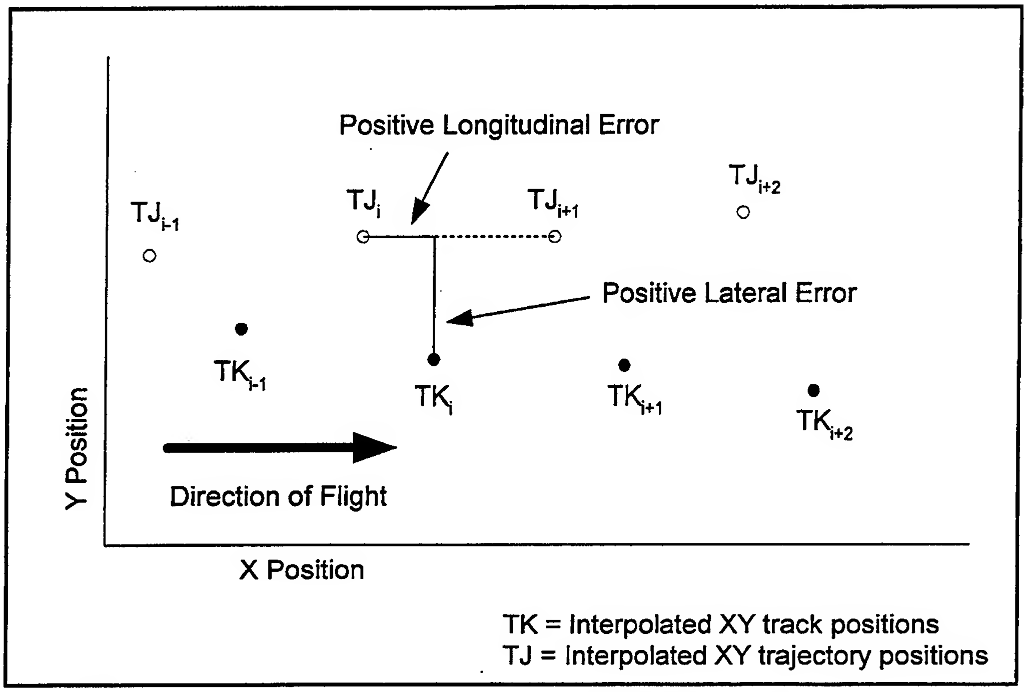


**Figure 2.2-1: Longitudinal and Lateral Errors**

### 2.2.2.2 Lateral Error

The lateral error represents the side to side, or cross track, difference between a track and its trajectory. This error, also represented in Figure 2.2-1, lies in the horizontal plane defined by a track point and two consecutive trajectory points. A positive lateral error indicates that the aircraft is to the right of the predicted trajectory at a corresponding point in time.

### 2.2.2.3 Vertical Error

The vertical error represents the difference between the tracked altitude and the predicted altitude. This error, depicted in Figure 2.2-2, lies perpendicular to the horizontal plane. A positive vertical error indicates that at a corresponding point in time the aircraft is above where the trajectory predicted it would be.

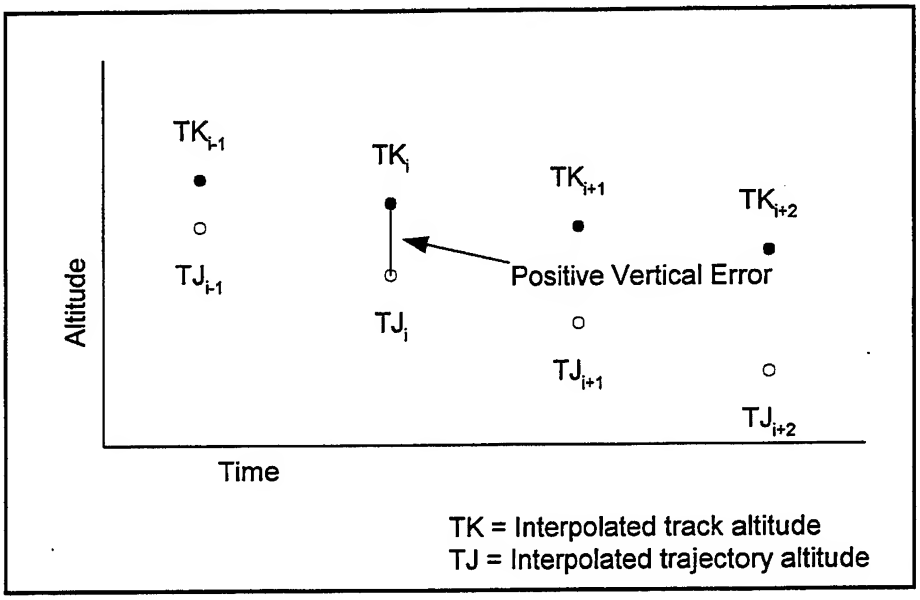


**Figure 2.2-2: Vertical Error**

## 2.2.3 Factors Definitions

Various factors that have the potential of affecting the accuracy of a trajectory modeler were examined during this study. These factors, which include trajectory build time, early trajectory, look ahead time, phase of flight, flight type and aircraft type, are defined in the following sections.

### 2.2.3.1 Trajectory Build Time

During the life of an aircraft track, a trajectory modeler computes numerous trajectories, each with an associated build time. Since, the trajectory accuracy metrics were computed at a number of sample times along an aircraft track it was necessary to establish criteria for selecting which trajectory to use in these computations. The trajectory selected for a specific sampling time along an aircraft track was the trajectory with the most recent build time, not exceeding the sample time. The determination of this factor is described in Section 2.5.1.1.

### 2.2.3.2 Early Trajectory

Depending on the method employed for creating trajectories (i.e., upon receipt of every track point or event driven), it is possible for a trajectory to be computed before the start of the track data. For this study, these are identified as "early trajectories". These trajectories are built strictly with the flight plan without HCS track information. The determination of this factor is described in Section 2.5.2.

### 2.2.3.3 Look Ahead Time

Associated with the error measures for a pair of points is a look ahead time. This look ahead time is the difference between the time point at which the metrics are computed for a sampled trajectory/track position and a base time. The base time represents the first calculation of the metrics taken among a sequence. The sequence starts by taking the current track point and a time coincident trajectory point off the currently available trajectory. The first point is the base time and then every parameter number of seconds, or look ahead time, into the future the metrics are

calculated on this same trajectory. The sequence iterates again every parameter number of seconds based on the sampling methodology defined in Section 2.5.1.1.

It is important to note that the look ahead time is based on the start of each sampling interval and is not directly related to the age of the trajectory as defined in other studies. For example, MITRE/CAASD defines look ahead time to be the difference between the trajectory build time and the time into the future a metric is calculated along that trajectory (Brudnicki, August 1995). In the ACT-250 study definition, a look ahead time of zero may be calculated on a trajectory that has an age of more than zero. The determination of this factor is described in Section 2.5.

#### 2.2.3.4 Phase of Flight

In the horizontal plane an aircraft can be considered to be either flying straight or turning. In the vertical plane an aircraft can be considered to be either flying level, ascending, or descending. The determination of these factors is described in Section 2.4.6.

#### 2.2.3.5 Flight Type

With respect to an ARTCC, an aircraft can be considered to be:

- overflight - the aircraft track begins outside the center boundary, flies through the center, then ends outside the center boundary
- departure - the aircraft track begins at an airport within the center and ends outside the center boundary
- arrival - the aircraft track begins outside the center boundary and ends at an airport within the center
- internal - the aircraft track begins and ends at an airport within the center.

The details for estimating this factor are presented in Section 2.4.2.

#### 2.2.3.6 Aircraft Type

The aircraft type is available as a part of an aircraft's flight plan message. For both DSTs, the aircraft type is an important factor in modeling the aircraft's flight profile. The frequency of the top 20 aircraft types were reported for each data set used (see Sections 3.1 and 4.1), however an analysis of the effect of the aircraft type as a factor was left for future study.

## 2.3 Data Sources

The source of the flight plan and track data used for this study was recorded at the Indianapolis (ZID) and Fort Worth (ZFW) ARTCCs. Section 2.4 describes the generic techniques used to process this data. Specific data processes and procedures required for URET and CTAS are described in Section 3.1 and Section 4.1, respectively.

## 2.4 Flight Plan and Track Data Processing

Figure 2.4-1 provides a data flow diagram logically describing the data files and processes used to process the flight plan and track data. This processing was automated through a UNIX shell script that performed numerous functions through six primary processes: Track Parser, EQUIP, RDTRACKS, TCP_P1, IN_CENTER, and PHASE_D. These are further described in the following subsections.

### 2.4.1 Track Parser

The Track Parser process consists of a UNIX shell script and C++ programs that parse and sort the track data for input into the Oracle database table RAW_TRACKS.

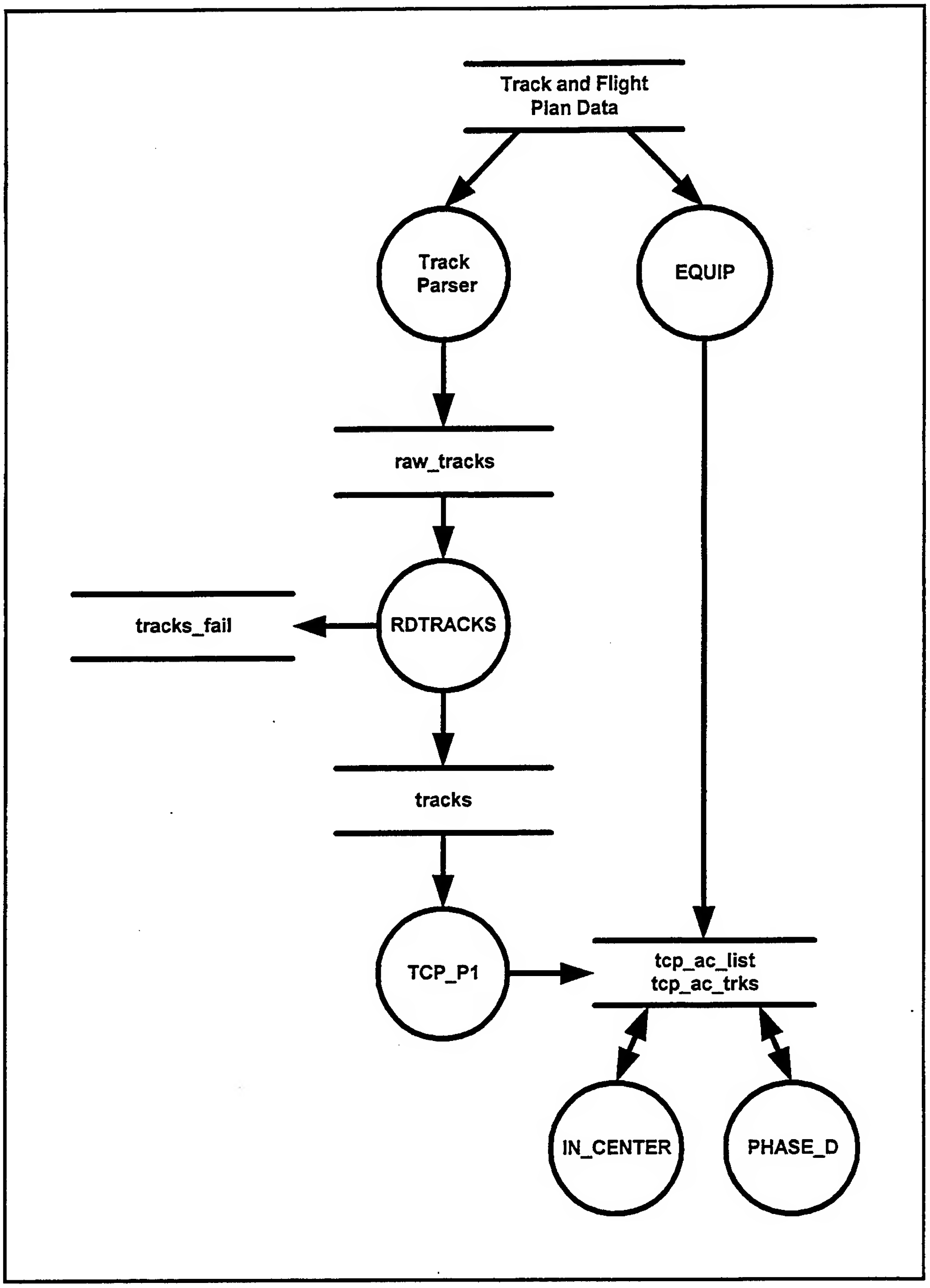


**Figure 2.4-1: Flight Plan and Track Data Processing**

## 2.4.2 EQUIP

EQUIP is a C program that extracts flight plan information and places it in the *tcp_ac_list* and *tcp_ac_trks* Oracle database tables. This information includes: the origin and destination airports, the flight type (arrival, departure, overflight, and internal), and the aircraft type and its equipage.

## 2.4.3 RDTRACKS

RDTRACKS is a C program that filters the RAW_TRACKS data to establish the "ground truth" tracks to which the trajectories are compared. RDTRACKS uses the URET and CTAS HCS tracks from their respective interface recorder files and produces files that are loaded into the TFM laboratory Oracle database to create the *tracks* and *tracks_fail* tables (described in WJHTC/ACT-250, 1999). The specific functions performed by RDTRACKS are described in the following subsections.

### 2.4.3.1 Correction of HCS Radar Track Position Reports

The radar track data supplied to the tools by the HCS contained inaccuracies and needed to be corrected before the error measurements could be made against the DST's trajectory predictions. For example, the following faults were found in the HCS track data:

- **Missing Track Reports -** Nominally the HCS supplies a new track report every 12 seconds. However, there were situations where the HCS omitted track reports, creating a gap in the position data (occasionally five or 10 minutes long). Short gaps (time gaps of less than two minutes) were patched by linear interpolation in all dimensions. Long gaps (time gaps of more than two minutes) were not patched and no accuracy measurements were made for these sections of the aircraft flight path.
- **Stationary Track Reports -** Frequently the HCS gave two or more successive track reports that had identical values for X, Y, and Z. That is, according to the HCS the aircraft had not moved (usually the HCS caught up with the next track report). This problem was fixed by linear interpolation.
- **Inconsistent Track Reports** - Because of its inertia, an aircraft is not able to make abrupt changes in velocity and position. Therefore, the distance traveled between position reports changes slowly. An abrupt change in track step size is not physically possible. A position report was considered to be inconsistent with the previous track report when an abrupt change occurred. Usually the position reports became consistent within a few track reports. Small amounts of inconsistent data were patched (i.e. less than two minutes), while large amounts (i.e. greater than two minutes) were not patched and measurements were not made during or beyond these gaps.
- **Jitter** – The position reports "bounce around" rather than following a smooth track as the aircraft is actually doing. This effect is noise or jitter on the position reports and is fairly small. It may be that the jitter exists in spite of the smoothing that the HCS does on the radar reports because of errors in the time data reported. As usual for real time processing systems, the data is not time stamped when it is collected. The time stamp is added later with reduced accuracy. For the statistical analyses performed in this study, the jitter was ignored. However, future studies may remove this additional source of error, using data smoothing techniques.

In addition to the track faults, there are differences in the methods by which URET and CTAS time stamp the track position reports from the HCS. RDTRACKS requires equally spaced track position reports, which URET supplies. CTAS track reports are not time stamped at equally spaced 12 second intervals but exactly as received downstream from the HCS interface.

Therefore, it was necessary to recover the HCS time values. This was done by rounding to the nearest whole second value and then these rounded values were rounded to the nearest integer multiple of 12 seconds. This was done in such a way as to minimize the total time adjustments for the entire track of the aircraft.

### 2.4.3.2 Track Processing Steps

The following processing was done to establish a good track history for an aircraft. If one value in a track report failed a test, the entire record was discarded. These tests did not ensure that a track report was accurate, but track reports that were clearly in error were excluded. If a track could not be initialized, the aircraft was not used in the study. At the start of each flight's track reports or following a large gap in time or spatial inconsistency, a flight's tracks are initialized. The initialization and continuous processing of the HCS track data is described below.

- **Prune Leading and Trailing Zeros** - Often the first one or two track reports for an aircraft had zero values for altitude. Similarly the last few records sometimes had zero altitude values. These reports were discarded.
- **Initialize Track** - The track was initialized by finding three good, contiguous track reports. A track report was considered good if it passed three tests:
  1. **Values Test** - The values test was used to catch gross errors in the aircraft position data. To pass the Values Test, Z had to be greater than zero and the absolute values of X and Y had to be less than 1000.
  2. **Delta Time Test** - To pass the Delta Time Test, the time of the track report had to be 12 seconds later than the time of the immediately preceding track report.
  3. **Fixed Delta Values Test** - To pass the Fixed Delta Values Test, the position of the aircraft in the horizontal (XY) plane must not have changed (in one 12 second step) by more than a maximum threshold value (3.0 nautical miles) nor less than a minimum threshold value (0.1 nautical miles). These threshold values correspond to aircraft speeds of 900 knots and 30 knots, respectively. In addition, the altitude of the aircraft could not have changed by more than a threshold value of 2000 feet, which corresponds to a climb or descent of 10,000 feet per minute. (Note that military aircraft were excluded from this study.)

After three good, contiguous track reports were found, the above three tests were repeated for each successive track report. Every record that passed all of the tests was passed unchanged to the next processing step in TCP_P1. If a report failed a test, an attempt was made, usually successfully, to fix the record by inserting new values obtained through interpolation between a previous good report and a later good report. There were two cases to handle: a time gap (missing data), and a bad data gap (one or more records were in error).

- **Time Gap Processing** - When a time gap in the data was found, a search was started for an acceptable next track report, starting with the current track report. Each successive track report was tested in turn. An acceptable next track report had to pass three tests: the Values Test described above, and the Variable Delta Values Test and the Maximum Time Gap Test, described below:
  1. **Variable Delta Values Test** - A prediction was made of where the aircraft would be if it maintained the same ground velocity as it had before the time gap. This predicted position was compared to the position reported by the candidate track report. The test was passed if the two positions were close enough to each other (three nautical miles). The average ground velocity was calculated using the last four position reports before the time gap.

2. **Maximum Time Gap Test** - The Maximum Time Gap Test determined if the time difference between the last good track report and the candidate next good report was less than or equal to two minutes. It was assumed that track data can be interpolated accurately for a time gap less than two minutes. This parameter setting of two minutes allowed up to nine successive position reports to be interpolated.

If a candidate track report failed either the Values Test or the Variable Delta Values Test, or both, the next track report was selected for testing. If the candidate track report passed the Values Test and Variable Delta Values Test, but failed the Maximum Time Gap Test, the track was re-initialized, whenever possible. If the track could not be re-initialized, it was terminated. If the search reached the end of the track data without finding a record which had passed all three tests, the track was terminated. If the candidate track report passed all three tests, it was output and used with the last good report to estimate, using linear interpolation, the missing track report positions in the time gap. The interpolation inserted track reports into the missing time slots and also replaced the track reports which failed the tests in the search for the next good report.

- **Bad Data Gap Processing** - A bad data gap was detected when a track report passed the Delta Time Test and the Values Test but failed the Fixed Delta Values Test. A search was then started to find the next good record. The search process was the same for a bad data gap as for a time gap. A search was started for an acceptable next track report, starting with the current track report. Each successive track report was tested in turn. An acceptable next track report had to pass three tests: the Values Test, the Variable Delta Values Test and the Maximum Time Gap Test, described above. When a candidate track report was found which passed all three tests, it was output and used with the last good report to estimate, using linear interpolation, the correct values of X, Y, and Z for the track report positions in the bad data gap. The interpolation inserted the corrected values into the track reports in the bad data gap. Then regular track processing was resumed. If a good next report could not be found, the track was terminated. If a next report passed the Values and the Variable Delta Values Tests, but failed the Maximum Time Gap Test, the track was re-initialized, if possible. If the track could not be re-initialized, it was terminated.

### 2.4.4 Track Conflict Probe

TCP_P1 is an Oracle Standard Query Language Plus (SQL/Plus) program that performs the interpolation of the track data. Although the HCS track reports normally are generated at 12-seconds intervals, for this study the track data was interpolated using a uniform 10-second time interval and synchronized with the hour.

An example of the relationship between recorded field data and interpolated aircraft tracks is shown in Figure 2.4-2. In this figure the **X**'s represent positional data generated by RDTRACKS at four time points. This data is specified in a time-of-day form and represents the aircraft's position at 16:25:13, 16:25:25, 16:25:37, 16:25:49, and 16:26:01. The **O**'s represent the interpolated positions with the time specified as the number of seconds elapsed since midnight. This interpolation was calculated using the MITRE/CAASD URET function CFP_POSIT (see Cale et. al., 1997, Section 3.1.9). This function uses a 2$^{nd}$ order method in which the acceleration is assumed to be constant throughout the interpolation interval. The ground speeds are needed as input for the quadratic interpolation method; if they are not available this method degenerates to a linear interpolation method.

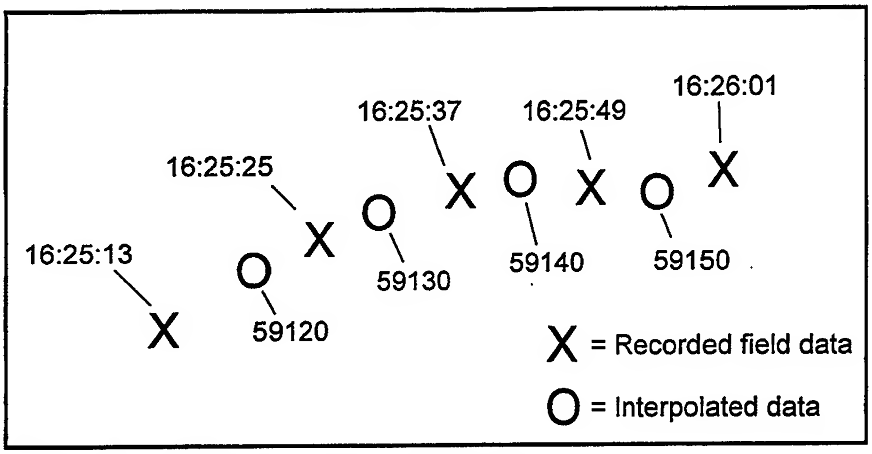


**Figure 2.4-2: Interpolation of Recorded Aircraft Track Data**

The following equations were used for quadratic interpolation where:

$x$ is the desired interpolated X coordinate at time $t$,
$x_1$ is the value of $x$ at time $t_1$,
$x_2$ is the value of $x$ at time $t_2$,
$y$ is the desired interpolated Y coordinate at time $t$,
$y_1$ is the value of $y$ at time $t_1$,
$y_2$ is the value of $y$ at time $t_2$, and $t_1 < t < t_2$.

In addition, for quadratic interpolation it was assumed that the acceleration was constant over the interpolation interval. The acceleration was then equal to the difference of the velocities at the start and end points of the interval divided by the length of the interval in time.

Let,

$v_1$ be the velocity of the aircraft at time $t_1$,
$v_2$ be the velocity of the aircraft at time $t_2$,
$v_{1x}$ and $v_{1y}$ be the X and Y components of the velocity $v_1$, and
$v_{2x}$ and $v_{2y}$ be the X and Y components of the velocity $v_2$.

Then the interpolated coordinate positions are

$$x = \frac{Ax_1 + Bx_2}{C} \qquad \textbf{Equation 2.4-1}$$

and

$$y = \frac{Dy_1 + Ey_2}{F} \qquad \textbf{Equation 2.4-2}$$

where

$$A = (v_{1x} - v_{2x})(t_2 - t)^2 + 2v_{2x}(t_2 - t_1)(t_2 - t) \qquad \textbf{Equation 2.4-3}$$

$$B = (v_{2x} - v_{1x})(t - t_1)^2 + 2v_{1x}(t_2 - t_1)(t - t_1) \qquad \textbf{Equation 2.4-4}$$

$$C = (v_{1x} + v_{2x})(t_2 - t_1)^2 \quad \textbf{Equation 2.4-5}$$

$$D = (v_{1y} - v_{2y})(t_2 - t)^2 + 2v_{2y}(t_2 - t_1)(t_2 - t) \quad \textbf{Equation 2.4-6}$$

$$E = (v_{2y} - v_{1y})(t - t_1)^2 + 2v_{1y}(t_2 - t_1)(t - t_1) \quad \textbf{Equation 2.4-7}$$

$$F = (v_{1y} + v_{2y})(t_2 - t_1)^2 \quad \textbf{Equation 2.4-8}$$

### 2.4.5 IN_CENTER

The IN_CENTER process determines if the interpolated track points fall within the center boundary. It uses an algorithm very similar to the MITRE/CAASD URET GM_REGN function (see Cale et. al., 1997, section 3.4.17) which determines if aircraft are within a protected or inhibited airspace. Since this study's application of this program was only interested in the end of an aircraft's track reports, all tracks were first flagged to be inside the center boundary. The algorithm was adapted to flag whether the track was outside the center boundary, starting from the end of the track reports and going backwards in time order. Processing was stopped for a flight's track as soon as it re-entered the center's airspace. For example, if an overflight had 100 interpolated track reports whose last 10 tracks were outside the center boundary (i.e. the 91st to 100th), this process determined each of the last 10 reports to be outside the Center boundary and the processing was terminated on the 90th track report when it was determined to be inside the Center.

The flag of inside or outside a center boundary, applied to the end of a flight's interpolated tracks, is utilized in the trajectory sampling process, since the trajectory prediction on tracks at the end of a flight outside the center are not processed for spatial prediction errors. This is an approximate method of excluding error calculations on the end portion of a flight transferring to another ARTCC and thus to another HCS and DST not included in the study.

### 2.4.6 PHASE_D

PHASE_D is a C program that determines the phase of flight of the aircraft in the horizontal and vertical directions, as discussed in the following subsections.

#### 2.4.6.1 Horizontal Phase of Flight

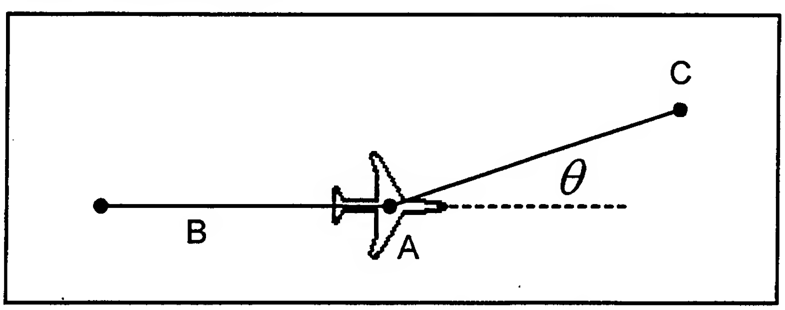


**Figure 2.4-3: Horizontal Phase of Flight**

The horizontal phase of flight for an aircraft, with respect to the ground, was defined as one of three states: straight, turning right, or turning left. The state was determined as follows: The point labeled A in Figure 2.4-3 represents the track point at which the aircraft's horizontal phase of

flight is being determined. The point labeled B is a point along the interpolated track a parametric number of points (one point in this study) earlier in time than the point being examined. The point labeled C is a point along the track a parametric number of points (one point in this study) later in time than the point being examined. Then the vector V is defined as the normalized vector cross product of the vector from point B to A and the vector from point A to C, i.e.:

$$V = \frac{V_{BA} \times V_{AC}}{\|V_{BA}\| \|V_{AC}\|} \quad \textbf{Equation 2.4-9}$$

where

$V_{BA}$ is the vector defined by joining B to A

and

$V_{AC}$ is the vector defined by joining A to C.

The magnitude of the vector $V$ is the sine of the local change in bearing angle of the aircraft and can be used to determine the horizontal phase of flight, i.e., if the aircraft is flying straight this angle will be zero or close to zero. If the aircraft is turning the sine will not be close to zero and the sign of the sine of this angle will indicate whether the aircraft is turning left or right.

Since the vectors $V_{BA}$ and $V_{AC}$ are in the horizontal XY plane their vector cross product $V$ is a vector perpendicular to the horizontal plane; i.e., coincident with the vertical or Z axis. In the NAS ARTCC coordinate system up is positive and down is negative. Therefore the sense of $V$ is positive for a left turn and negative for a right turn. To determine whether the aircraft is flying straight or turning, the magnitude of $V$ is compared to a threshold to minimize the effect of track position noise on the measurement.

Let the coordinates of the point A be $x_a$ and $y_a$, the coordinates of the point B be $x_b$ and $v_b$, and the coordinates of the point C be $x_c$ and $y_c$. Then the components of the vectors $V_{BA}$ and $V_{AC}$ are:

$$V_{BA} = \begin{bmatrix} x_a - x_b \\ y_a - y_b \\ z_a - z_b \end{bmatrix} = \begin{bmatrix} v_{BAx} \\ v_{BAy} \\ v_{BAz} \end{bmatrix} \quad \textbf{Equation 2.4-10}$$

$$V_{AC} = \begin{bmatrix} x_c - x_a \\ y_c - y_a \\ z_c - z_a \end{bmatrix} = \begin{bmatrix} v_{ACx} \\ v_{ACy} \\ v_{ACz} \end{bmatrix} \quad \textbf{Equation 2.4-11}$$

Since the vectors are defined to be in the horizontal plane, the z components are all zero. The norms or magnitudes of the vectors are:

$$\|V_{BA}\| = \sqrt{v_{BAx}^2 + v_{BAy}^2} \quad \textbf{Equation 2.4-12}$$

$$\|V_{AC}\| = \sqrt{v_{ACx}^2 + v_{ACy}^2} \quad \textbf{Equation 2.4-13}$$

The cross product of the vectors $V_{BA}$ and $V_{AC}$ has a single component in the z direction, which is calculated as:

$$Q = v_{BAx} v_{ACy} - v_{ACx} v_{BAy}$$ **Equation 2.4-14**

Normalizing the cross product by dividing by the magnitudes of the vectors $V_{BA}$ and $V_{AC}$ gives the sine of the angle between the vectors which is the local change in aircraft course bearing $\theta$.

$$\sin\theta = \frac{Q}{\|V_{BA}\|\|V_{AC}\|}$$ **Equation 2.4-15**

and

$$\theta = \sin^{-1}\left(\frac{Q}{\|V_{BA}\|\|V_{AC}\|}\right)$$ **Equation 2.4-16**

This calculation of $\theta$ is valid for angles of up to 90 degrees, left or right. For angles from 90 degrees to 180 degrees, left or right, the value of the angle is incorrect, but the sign of the angle is correct. For turn angles greater than 180 degrees, the angle and the sign are incorrect.

The absolute value of $\sin\theta$ is compared to a threshold to determine whether or not the aircraft is turning. If the aircraft is turning, a positive value of $\sin\theta$ says the aircraft is turning to the left, a negative value says the aircraft is turning to the right.

In this study, a turn is determined by a nine degree angle (or greater) generated by the two segments drawn from the previous position to the current position and the current position to the next position report. The threshold was determined from observation of several flights in both Indianapolis and Fort Worth ARTCCs. In the future, data smoothing techniques may be employed to further enhance the algorithm changing this threshold angle.

### 2.4.6.2 Vertical Phase of Flight

The vertical phase of flight for an aircraft was defined as one of three states: level, ascending, or descending. This state was determined by selecting a track data point a parametric number of points (one point in this study) earlier than the point being examined and a track data point a parametric number of points (one point in this study) later than the point being examined. The altitude difference between the earlier point and the later point divided by the time difference between the two points is an estimate of the aircraft's rate of climb or descent. If the absolute value of the measured rate of climb is less than a parametric threshold value (150 feet in this study) the aircraft is considered to be in level flight. If the measured rate of climb is greater than a positive parametric threshold (150 feet in this study) the aircraft is considered to be ascending. If the measured rate of climb is less than a negative parametric threshold (-150 feet in this study), then the aircraft is considered to be descending.

## 2.5 Trajectory Data Processing and Trajectory Report Generation

Figure 2.5-1 provides a data flow diagram logically describing the data files and processes used to sample the trajectory data and to generate the trajectory reports. This processing consists of the Trajectory Sampling Program (TJS) and the Trajectory Report Generation Program (TRG), discussed in subsections 2.5.1 and 2.5.2.

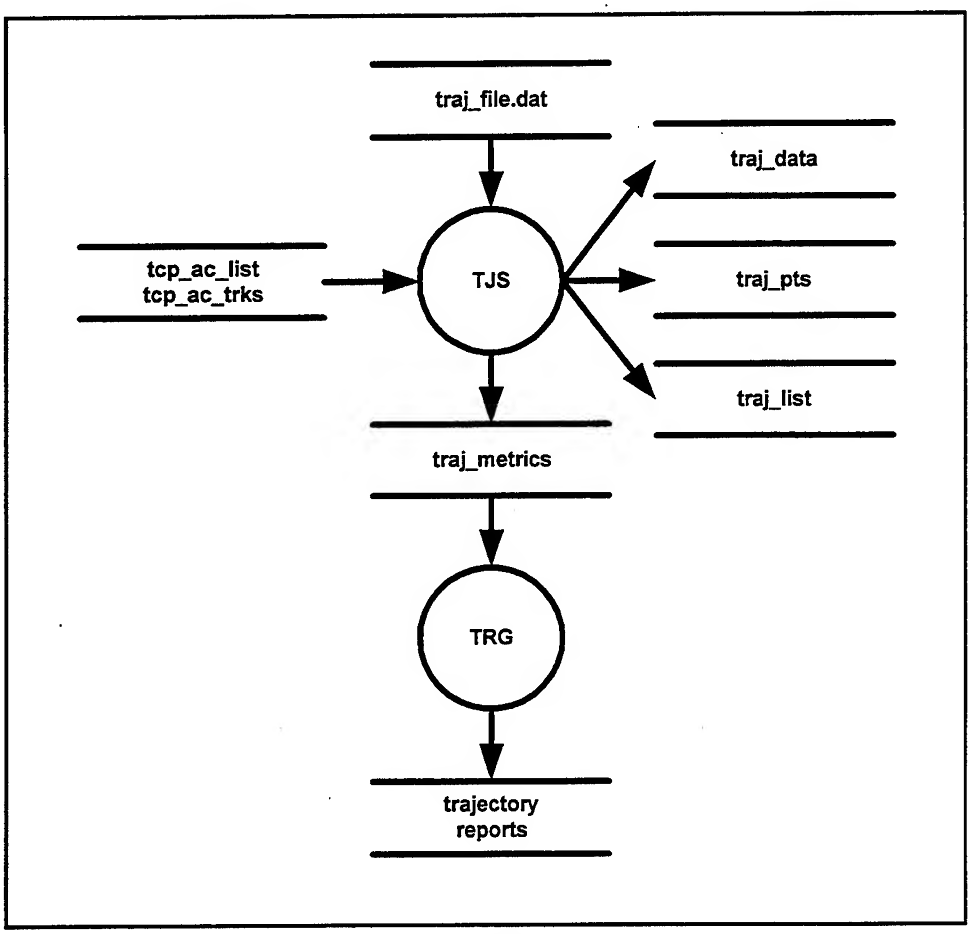


**Figure 2.5-1: Trajectory Data Processing and Trajectory Report Generation**

### 2.5.1 Trajectory Sampling Program (TJS)

The Trajectory Sampling Program (TJS) is a C++ program that uses the Oracle Pro*C/C++ Precompiler (Release 8.0) to interface with the Oracle database in the TFM laboratory.

#### 2.5.1.1 Trajectory Sampling

The URET and CTAS trajectory modelers evaluated by this study both compute time-based four-dimensional trajectories. However, they have different design philosophies regarding when these trajectories are calculated.

URET calculates an initial trajectory for each aircraft, then constructs a new trajectory for a given aircraft whenever:

1. A new flight plan or flight plan amendment message is received from the HCS, or new or updated interfacility flight plan information is received from a neighboring URET system.

2. A hold message is received from the HCS that indicates the aircraft is entering or leaving a holding pattern.

3. URET determines that a new trajectory is necessary to reconform an aircraft's trajectory with the aircraft's actual position. This can happen when the HCS track data is found to be a parametric distance (nominally 1.5 to 2.5 nautical miles) from the trajectory or if the current trajectory is older than a parametric value (e.g. 20 minutes).

CTAS, on the other hand, calculates a new trajectory for each aircraft upon receipt of HCS track data each processing cycle.

ACT-250 devised a trajectory sampling technique that is independent of the design approach of either trajectory modeler. The line in Figure 2.5-2 labeled "Track" represents the time line for an aircraft track. The time point labeled $T_S$ represents the initial interpolated track point. The sampling time to start computing metrics for this track is represented by $T_0$, where

$$T_0 = T_S + \text{TRAJ\_DELTA\_TIME} \qquad \textbf{Equation 2.5-1}$$

TRAJ_DELTA_TIME is a parametric value (40 seconds) which establishes the starting time at a point where the track is more stable.

The trajectories for this example aircraft are presented in Figure 2.5-2 by the time lines labeled $Traj_0$, $Traj_1$, $Traj_2$, and $Traj_3$. The trajectory to be sampled for a particular track sampling time is the trajectory with the latest trajectory build time not exceeding the track sampling time. Selected trajectories were interpolated using techniques similar to the techniques for interpolating tracks described in Section 2.4.4. In Figure 2.5-2, $Traj_0$ would be sampled for sampling time $T_0$. This point is labeled $T_{0,0}$ and represents the look ahead time of zero seconds for the trajectory sampling time $T_0$.

Metrics would be computed at the time point labeled $T_0$ and at the incremented time points $T_{0,1}$ and $T_{0,2}$ where

$$T_{i,j+1} = T_{i,j} + \text{TRAJ\_LOOKAHEAD\_TIME} \qquad \textbf{Equation 2.5-2}$$

TRAJ_LOOKAHEAD_TIME is the parametric sampling interval (300 seconds) for a specific sampling time.

The trajectory sampling process continues until either: the end of the track is reached, the end of the trajectory is reached, or the time exceeds $T_0$ + TRAJ_LOOKAHEAD_WIN, a parametric input (1800 seconds). Then the next track sampling time $T_i$ will be computed as:

$$T_{i+1} = T_i + \text{TRAJ\_SAMPLE\_TIME} \qquad \textbf{Equation 2.5-3}$$

TRAJ_SAMPLE_TIME is the parametric sampling interval (120 seconds) for sampling a specific track.

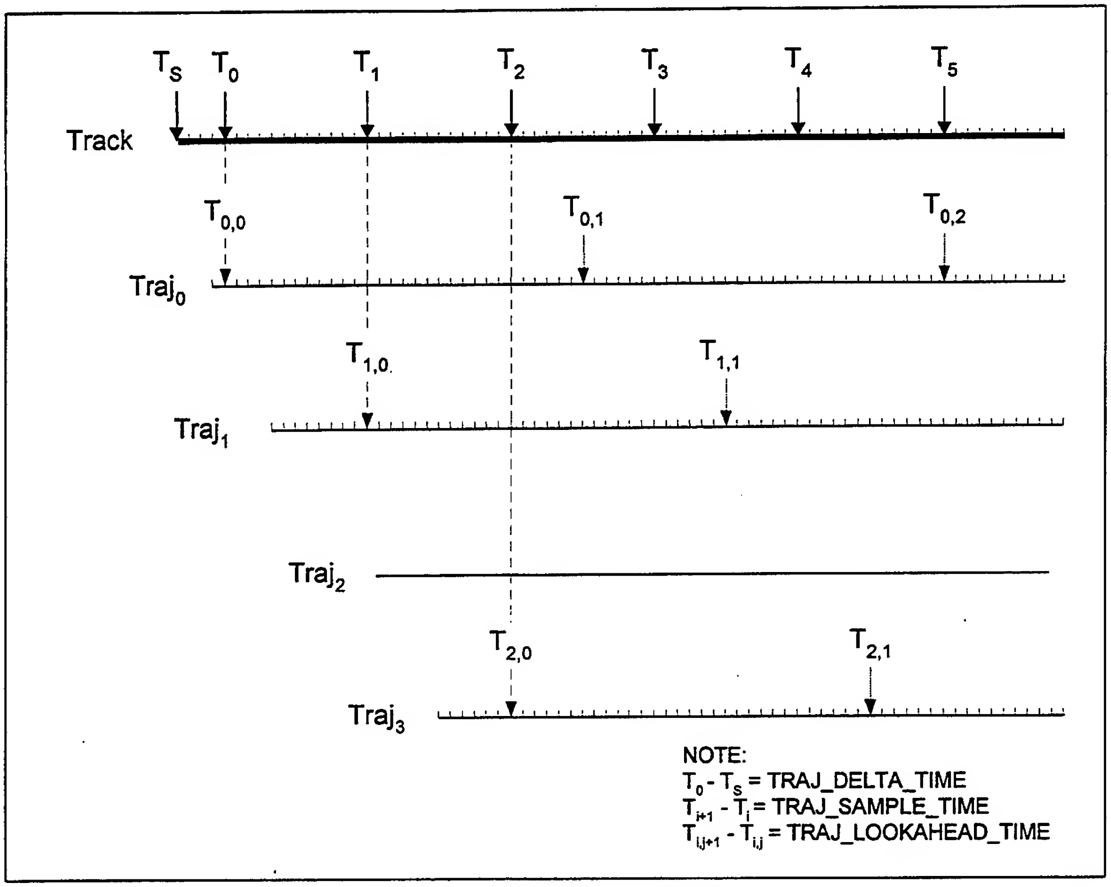


**Figure 2.5-2: Interval Based Sampling**

### 2.5.1.2 Estimation of the Metrics

Estimations of the error metrics (the horizontal, longitudinal, lateral, and vertical errors defined in Section 2.2.2) were calculated at a particular time point T as follows. Point A in Figure 2.5-3 represents the actual position of the aircraft at time T, point B represents the predicted position of the aircraft at time T along the trajectory and point C represents the next predicted position along the interpolated trajectory. Line segment AB represents the horizontal error. Point D is defined as the point along the line segment BC at which the angle formed by the line segments BD and DA is a right angle. Then the longitudinal error is represented by the directed line segment BD, and the lateral error is represented by the directed line segment DA.

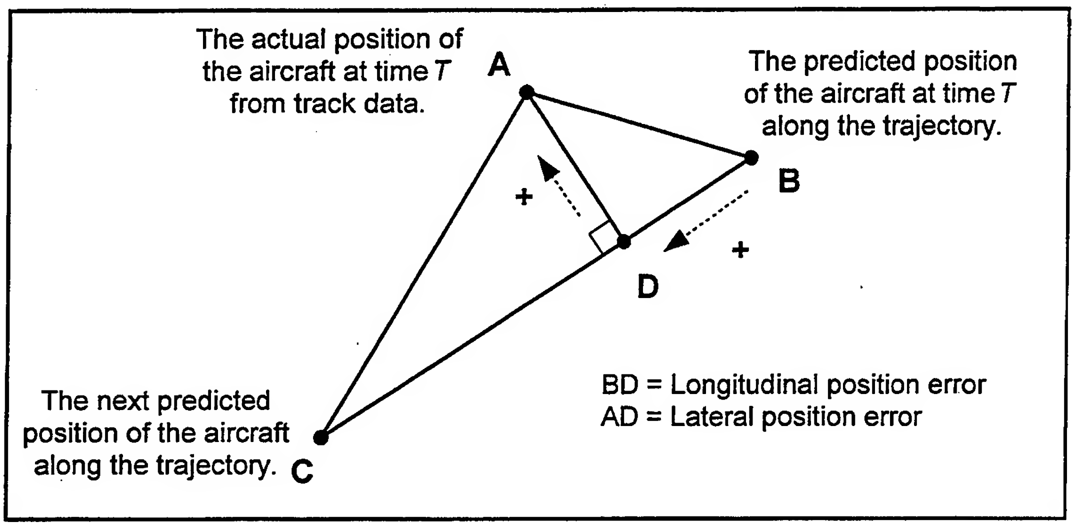


**Figure 2.5-3: XY Error Geometry**

The method used to calculate these errors is similar to the method used by the URET function GM_PTLINE (see Cale et. al., February 1997, section 3.4.16), described as follows:

As well as the normal case depicted in Figure 2.5-3, there are three special cases: (1) the line BC is parallel to the x-axis, (2) the line BC is parallel to the y-axis, and (3) the points B and C are identical.

If the coordinates of the point A are denoted as $(x_A, y_A, z_A)$, the coordinates of the point B as $(x_B, y_B, z_B)$ and the coordinates of the point C as $(x_C, y_C, z_C)$, then:

1) <u>Normal Case</u>: The slope m of the line BC is then

$$m = \frac{(y_C - y_B)}{(x_C - x_B)} \qquad \textbf{Equation 2.5-4}$$

The slope $m'$ of the line through A perpendicular to BC is the negative reciprocal of $m$, that is

$$m' = -\frac{1}{m} \qquad \textbf{Equation 2.5-5}$$

The equation of the line through the point A with the slope $m'$ is

$$y = y_A + m'(x - x_A) \qquad \textbf{Equation 2.5-6}$$

The equation of the line through the point B with the slope $m$ is

$$y = y_B + m(x - x_B) \qquad \textbf{Equation 2.5-7}$$

The point of intersection D, denoted as $(x_D, y_D)$, is the simultaneous solution of these two equations:

$$x_D = \frac{y_B - y_A + m' x_A - m x_B}{m' - m}$$ **Equation 2.5-8**

$$y_D = \frac{m m' (x_B - x_A) + m y_A - m' y_B}{m - m'}$$ **Equation 2.5-9**

2) <u>Special Case 1: BC is parallel to the x axis</u>: This is true if and only if $y_B = y_C$. Then the equations for the coordinates of the point D are

$$x_D = x_A$$ **Equation 2.5-10**

and

$$y_D = y_B$$ **Equation 2.5-11**

3) <u>Special Case 2: BC is parallel to the y axis</u>: This is true if and only if $x_B = x_C$. Then the equations for the coordinates of the point D are

$$x_D = x_B$$ **Equation 2.5-12**

and

$$y_D = y_A$$ **Equation 2.5-13**

4) <u>Special Case 3: Points B and C are identical</u>: There is no solution. This case will not occur when the input data for this calculation is valid.

After the coordinates of D have been computed, the longitudinal and lateral errors can be calculated as follows:

The longitudinal error $E_{long}$ is the length of the line BD, which is

$$E_{long} = \sqrt{(x_D - x_B)^2 + (y_D - y_B)^2}$$ **Equation 2.5-14**

The lateral error $E_{lat}$ is the length of the line AD, which is

$$E_{lat} = \sqrt{(x_D - x_A)^2 + (y_D - y_A)^2}$$ **Equation 2.5-15**

The following process was used to determine the signs for the longitudinal and lateral errors. Referring again to Figure 2.5-3 the components of the vectors $V_{BA}$ and $V_{BC}$ are:

$$V_{BA} = \begin{bmatrix} x_A - x_B \\ y_A - y_B \\ z_A - z_B \end{bmatrix} = \begin{bmatrix} v_{BA_x} \\ v_{BA_y} \\ 0 \end{bmatrix}$$ **Equation 2.5-16**

$$V_{BC} = \begin{bmatrix} x_C - x_B \\ y_C - y_B \\ z_C - z_B \end{bmatrix} = \begin{bmatrix} v_{BC_x} \\ v_{BC_y} \\ 0 \end{bmatrix}$$ **Equation 2.5-17**

The scalar dot product of the vectors $V_{BA}$ and $V_{BC}$ is a scalar quantity, which can be calculated:

$$v_{BA_x} v_{BC_x} + v_{BA_y} v_{BC_y}$$ **Equation 2.5-18**

The sign of the longitudinal error was considered positive if this scalar quantity was positive (i.e. track position ahead of trajectory predicted position).

The vector cross product of the vectors $V_{BA}$ and $V_{BC}$ has a single component in the z direction, which can be calculated:

$$v_{BA_x} v_{BC_y} - v_{BA_y} v_{BC_x}$$ **Equation 2.5-19**

The sign of the lateral error was considered positive if the value of this component was positive (i.e. track position to the right of trajectory predicted position).

The vertical error $E_{vert}$ is the signed difference between the altitudes (i.e., the z coordinates) of the two corresponding points from the interpolated track data and the interpolated trajectory data.

$$E_{vert} = z_A - z_B$$ **Equation 2.5-20**

The vertical error is positive when the track position is above the trajectory predicted position.

### 2.5.2 Trajectory Report Generation

The Trajectory Report Generation (TRG) process is a UNIX shell script and a series of SQL/PL programs that generate several categories of reports, including:

1. Summary and overall statistics on all data including the track and trajectory data.
2. Statistics on the trajectory metrics. There are seven reports for look ahead times equal to zero, 300, 600, 900, 1200, 1500, and 1800 seconds, used in Sections 3.3.1 and 4.3.1.
3. Summary and overall descriptive statistics on the trajectory metrics data, excluding trajectories for which the EARLY_TRAJ_FLAG was set. The EARLY_TRAJ_FLAG flags a trajectory with a build time earlier than the first HCS track report.
4. Descriptive statistics on the trajectory metrics for the seven look ahead times, excluding trajectories for which the EARLY_TRAJ_FLAG was set.

5. A listing of ACID_CID, sample time, trajectory build time, lateral error, longitudinal error, horizontal error, vertical error, and track quality[1] for each look ahead time. This data was used for inferential statistical analysis.
6. Descriptive statistics for the trajectory metrics for each of the seven look ahead times for the horizontal phase of flight including straight and turning, used in Sections 3.3.3 and 4.3.3.
7. Descriptive statistics for the trajectory metrics for each of the seven look ahead times for the vertical phase of flight including level, ascending, and descending, used in Sections 3.3.4 and 4.3.4.
8. Descriptive statistics for the trajectory metrics for each of the seven look ahead times for the following four flight type cases:
   - Overflights
   - Departures
   - Arrivals
   - Internals

   This TRG report was used in Sections 3.3.2 and 4.3.2.
9. Descriptive statistics for the trajectory metrics for each of the given look ahead times for the top ten occurring aircraft types listed in Sections 3.1.5 and 4.1.5 for URET and CTAS, respectively. The use of this TRG report will be left for future studies.
10. Descriptive statistics for the trajectory metrics for each of the given look ahead times for general aviation airlines versus commercial airlines. The use of this TRG report will be left for future studies.

Note: All reports repeated with samples only above 18,000 feet.

## 2.6 Analysis Methodology

A statistical analysis of the trajectory accuracy of URET and CTAS was conducted. The results of these analyses are presented in Section 3.3 for URET and Section 4.3 for CTAS. The analyses consist of aggregate performance information, such as the number of samples and trajectories analyzed; context related statistics, such as the percentage of flights modeled; and actual trajectory accuracy statistics. For the trajectory accuracy statistics, the analysis is presented in tables delineating the results of inferential statistical tests performed and plots of the mean errors partitioned by selected factors, including look ahead time, phase of flight, and flight type. In addition, complete descriptive statistics for both analyses are contained in Appendices A and B. The following subsections provided additional information on each type of analysis that was conducted.

### 2.6.1 Aggregate Trajectory Performance Analysis

For the aggregate performance information, counts are reported for the total number of trajectories built, the number of trajectories sampled, and the number of flights processed. The duration of the trajectories and duration of each trajectory analyzed also provide the reader with the magnitude of the analysis coverage. Other aggregate performance information includes the total number of sample points used in the study.

### 2.6.2 Context Related Trajectory Performance Analysis

The context related statistics provide the reader with knowledge about the scope of the results, including the percentage of valid flights sampled, sampled trajectory age, and ratio of prediction coverage.

[1] Track quality is the percentage of track position reports which have been altered by the RDTRACKS processing.

#### 2.6.2.1 Percentage of Valid Flights Sampled

The first, and probably most important, of the context related statistics is the percentage of valid flights sampled. Two conditions or events were required for a flight to be analyzed: it had to have both flight plan information from the HCS and trajectory prediction data from the DST. Referring to Figure 2.6-1, area "a" defines the valid aircraft flights for analysis. To be valid, an aircraft flight must have (1) a HCS flight plan message, (2) a set of HCS track position reports that have been verified by the RDTRACKS program discussed in Section 2.4.3, and (3) trajectory predictions from the DST. For the events under area "a" in Figure 2.6-1, some time overlap exists between the trajectory prediction and the track position reports. The area "c" includes valid aircraft flights with all the required HCS position data but insufficient trajectory prediction data (i.e., either no trajectory at all or not overlapping in time with the track data). The area "b" in Figure 2.6-1 includes the trajectories built without valid aircraft data, defined as lacking at least one of the HCS data defined above (i.e. flight plan, track data, time overlap, and positional verification).

It is important to quantify these events, since the analysis is based only on area "a". A DST's own bias in building trajectories can influence the trajectory accuracy statistics. In other words, the results are based only on situations when the DST chose to build a trajectory and obviously not on situations where it did not for whatever reason. Therefore, it is important to interpret the trajectory results in context of the trajectories it built. Referring to Figure 2.6-1, the ratio of area "a" to the sum of areas "a" and "c" defines the DST's fraction of valid flights with sampled trajectory prediction. It is reported as the percentage of the valid aircraft flights that have sampled trajectory prediction.

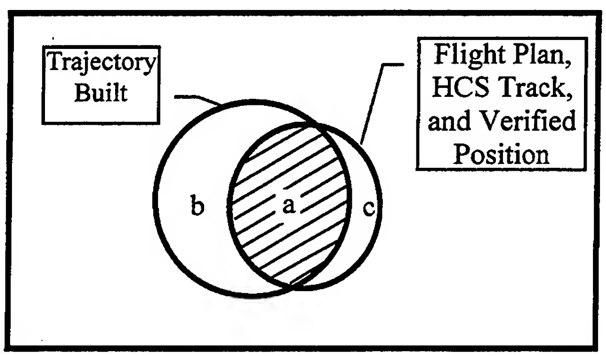


**Figure 2.6-1: Trajectory and Aircraft Flight Events Venn Diagram**

#### 2.6.2.2 Ratio of Prediction Coverage

Another statistic useful in setting the context of the study estimates the trajectory prediction coverage over the track time analyzed. It is possible for trajectories to exist for a short prediction time with high accuracy while another DST could make predictions for the entire length of HCS track reports with less accuracy. This statistic quantifies this situation. It is defined as the ratio of the total time that the trajectories were predicted and captured for the analysis over the total time that the track was captured for analysis.

Referring to Equation 2.6-1, the trajectory prediction coverage is measured by taking each aircraft in area "a" in Figure 2.6-1 and calculating the difference between its last sampled trajectory's end time and its first sampled trajectory's start time. This difference is then divided by the difference between the end time of its last track report analyzed and the start time of its first track report.

This value will always be less than one, since trajectories are sampled and analyzed starting at 40 seconds past the beginning of the track start time and end with the shorter of the two, either track or trajectory. If a trajectory ends before the track end time, the ratio will be increasingly smaller than one, and if the track ends earlier the ratio will reach a maximum close to one due to the initial 40 seconds delay in sampling.

**Equation 2.6—1**

$$\text{ratio of prediction coverage} = \frac{(\text{last trajectory's end time - first trajectory's start time})}{(\text{track end time - track start time})}$$

For this analysis, the average and standard deviation of the ratio of prediction coverage is reported, as well as a 95 percent confidence interval around the sample mean. Also a histogram and quantile table (i.e. a table listing the percentiles from 0 to 100) are presented.

#### 2.6.2.3 Sampled Trajectory Age

Another descriptive value that defines the context of the analysis is the age of the trajectory at the look ahead time of zero. Referring to the sampling process defined in Section 2.5.1, the longer a DST retains a trajectory, the older the age of the trajectory at each sampling interval. The age of the trajectory at each sample time is proportional to the frequency trajectories are rebuilt by the DST. In general, a DST that builds trajectories more frequently will have a smaller average trajectory age. Although there may be a correlation between trajectory age and trajectory prediction accuracy, it is also effected by the reasons for the refresh, as well as other factors.

### 2.6.3 Trajectory Accuracy Analysis

Basic descriptive statistics were calculated for each of the trajectory metrics. These statistics include the average, standard deviation, and maximum and minimum values, for: horizontal error, lateral error, absolute value of lateral error, longitudinal error, absolute value of longitudinal error, vertical error, and absolute value of vertical error. These descriptive statistics are reported for each look ahead time as well as several identified factors. Inferential statistics were used to determine whether the levels of the identified factors were statistically different and had a significant effect on each performance value. For example, at a look ahead time of zero, the hypothesis is tested on whether the mean horizontal error is equivalent in a turn or a straight path. This approach was chosen because of the application of the Central Limit Theorem (CLT), which allows the approximation of a Normal Distribution on a sample mean with a sufficiently large sample size (Devore, 1987). In this study, the sample sizes ranged in the thousands.

For the inferential statistics, three statistical tests were performed[2]:

1. Levene Test which determines if the particular performance value's (e.g. horizontal error) variances are significantly different statistically between the levels (i.e. by look ahead time, different flight types or phases of flight) (Neter, 1996)
2. Welch Test which determines if the particular performance value's sample means are significantly different statistically between the levels (Kelton and Law, 1991)

[2] The three statistical tests defined, Levene, Welch, and Tukey-Kramer, are described in more detail in Appendix A.0. Descriptions of the histograms, box plots, and mean comparison plots (i.e. diamond and circle plots) are also presented in Appendix A.0.

3. Tukey-Kramer Test which determines which of the particular pair or pairs of performance value's sample means are significantly different statistically between the levels (SAS Institute, 1995)

There are many factors which can affect the accuracy of the predictions of the flight path. Section 2.2.3 identifies the factors used in this report; other factors can be analyzed in the future if resources permit.

Table 2.6-1 lists the types of statistical analyses that were performed on each of the identified factors. The analyses included descriptive statistics (tables are presented in Appendix A), or inferential statistics in which hypothesis testing of the means and variances were performed (presented in both Appendix A and summarized in the Sections 3.3 and 4.3 for URET and CTAS, respectively). For several of the factors, both descriptive and inferential statistical analysis was performed. Table 2.6-1 also identifies whether graphical information is presented. Inferential statistics and graphical plots (i.e. histograms and quantile tables) were calculated for a subset of the available look ahead times, including zero, 600, 1200, and 1800 seconds (presented in Appendix A). Also, the Sample Mean Plots are presented in Sections 3.3 and 4.3 for URET and CTAS, respectively, and Sample Standard Deviation Plots are presented in Appendix B. The signed values of the error metrics (e.g. average lateral error) were used for these more exhaustive inferential techniques, since the sample mean acts as a measure of the bias of the trajectory predictions and the standard deviation as a measure of the uncertainty. The absolute value statistics (e.g. average absolute value of lateral error), which are also a useful measure of the uncertainty, have been included in the descriptive statistics reported in Appendix A.

Since the DSTs examined were designed to model IFR aircraft in en route airspace, this study needed a method to generically separate aircraft tracked by the HCS that may have been handed off and were entering a terminal airspace, from other strictly en route flights. The approximate method chosen was to perform two studies, one for all aircraft tracks captured by the HCS and a second performed on HCS track reports above 18,000 feet, which is well above all terminal airspace in the Center's under study. Therefore, all factors including look ahead time were analyzed twice: once with all the sampled track points and then with only sampled track reports above 18,000 feet.

**Table 2.6-1: Analysis Summary**

| Factor For Samples at All Altitudes / Above FL180 | Descriptive Statistics | Inferential Statistics | Sample Mean / Std. Dev. Plots | Histograms / Quantiles |
|---|---|---|---|---|
| Look Ahead Time | Yes | Yes | Yes | Yes |
| Flight Type | Yes | Yes | Yes | No |
| Phase of Flight Horizontal | Yes | Yes | Yes | No |
| Phase of Flight Vertical | Yes | Yes | Yes | No |

# 3. URET Study Results and Observations

The results and observations presented in this section are based on the analysis of over seven hours of data recorded at the Indianapolis ARTCC (ZID). Specific information describing the scenario is presented in Section 3.1. Section 3.2 provides detailed information about one aircraft flight in the study which demonstrates the study's methodology, and Section 3.3 presents the results of the application of the trajectory accuracy metrics to URET.

## 3.1 Scenario Description

Figure 3.1-1 provides a data flow diagram logically describing the data files and processes used to obtain the flight plan, track, and trajectory data used for the URET analysis. For this study, data was collected from the URET installation at ZID. The source of the data was a Monitor Test and Recording (MTR) file, created at the output of the General Purpose Output Interface Module (GIM), containing the HCS flight plans, flight plan amendments, and track messages sent to URET over a 7.5 hour period on February 27, 1998. The weather data for the same time period was also recorded.

The scenario file, identified as *sn022798.dat* in Figure 3.1-1, was created using the MITRE/CAASD Reverse Host Converge/Merge Process (RHCMP) program (Byrdsong et. al., 1997). The *sn022798.dat* file is an ASCII file containing event records, which are primarily the NAS Host computer messages. These event records contain the time of the event, the event type, the aircraft identifier, and the aircraft's computer identifier followed by the event subfield. The format of these records is defined in Lindsay, 1998. This *sn022798.dat* file was then used as input to both the Flight Plan and Track Data Processing described in Section 2.4, and to URET D3A (specifically, URET Release D3A_R3_P2) in the WJHTC TFM laboratory.

The trajectory information was recorded by URET's Data Recorder program in binary format. The trajectory data is first parsed into a large ASCII file by MITRE's Data Collection Post Processor, DCPP, (Byrdsong et. al., 1997). This file, *ssg_file,* still needs to be parsed further and converted to a generic format. The *ssg_file* is input into a program composed of a UNIX shell script and C++ program called *up_scr*. This program parses the trajectory data into a generic ASCII file called *traj_file.dat*, which was input to the Trajectory Data Processing described in Section 2.5. The formats of the *ssg_file* and the *traj_file.dat* files are described in WJHTC/ACT-250, 1999.

Tables 3.1-1 and 3.1-2 summarize the characteristics of the airspace and the aircraft flights through the airspace, respectively, for the subject scenario.

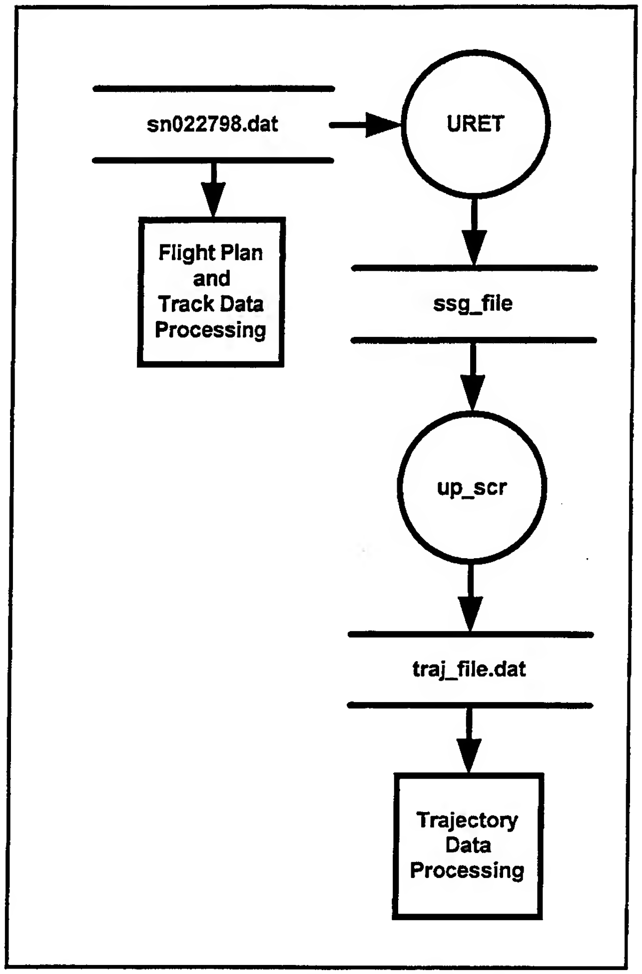

**Figure 3.1-1: URET Data Sources**

## 3.1.1 Airspace Definition

Table 3.1-1 summarizes the spatial and time boundaries of the ZID data sample used.

**Table 3.1-1: ZID Airspace Definition for URET Study**

| | |
|---|---|
| Airspace | Indianapolis Center (ZID) |
| Altitude | 0 to 60,000 feet |
| Horizontal boundaries | Defined by the high altitude sectors |
| Date | February 27, 1998 |
| Start time | 12:01:31 UTC (6:01 a.m. local time) |
| End time | 19:33:10 UTC (1:33 p.m. local time) |
| Duration | 07:31:39 or 27,099 seconds |

### 3.1.2 Aircraft Counts

Table 3.1-2 delineates the counts of aircraft flights in the sample of air traffic analyzed.

**Table 3.1-2: Aircraft Counts for URET Study**

| | |
|---|---|
| Total number in sample (IFR) | 2656 |
| Number excluded | 150 (5.65 %) |
| Number processed | 2506 (94.4 % of total) |
| Number of airliners | 1913 |
| Number of General Aviation aircraft | 593 |
| Number of jets in the top 20 aircraft | 15 |
| Number of turboprops in the top 20 aircraft | 5 |
| Number of piston aircraft | 0 |
| Average length of track | 34.7 minutes, 2082 seconds, or 174 position reports |
| Number of overflights | 1115 (44.5 %) |
| Number of departures | 692 (27.6 %) |
| Number of arrivals | 630 (25.1 %) |
| Number of internal flights | 69 (2.8 %) |

### 3.1.3 Excluded Flights

In measuring the accuracy of track predictions, the true positions of the aircraft are assumed to be the positions reported by the HCS. For some aircraft, it is clear that the HCS reported positions are not correct. Track processing algorithms were used to correct the position data where possible, as described in Section 2.4. When it was not possible to correct the data, the individual tracks and in some cases entire flights were deleted from the scenario being examined, as discussed in the following sections. Statistics were collected on an aircraft flight only if both a track and a set of predicted trajectories were available. For this analysis of URET, there were three categories of excluded aircraft totaling 150 flights that were deleted from the original set of 2656 IFR flights (a reduction of 5.65 %).

#### 3.1.3.1 Military Flights

Since it is often not possible from flight plan data to accurately predict the flight paths of military flights, which usually are doing either gunnery practice or aerial re-fueling maneuvers, military flights were excluded from the analysis. This was done by selecting out all of the flights which had a call sign containing more than three leading alphabetic characters (e.g., ANVIL, CODER, RACER, SABER, STEEL). Although this is not an exact definition of military aircraft, it was considered to be sufficient for this study. 79 military flights were excluded.

#### 3.1.3.2 Non-initialized Flights

As discussed in Section 2.4, sometimes the HCS processing algorithms are unable to establish a consistent track for the aircraft. There were 18 flights excluded for this reason.

#### 3.1.3.3 Uncertain Position Flights

The processing of the HCS track data requires correcting some of the track reports which are clearly in error. For example, as discussed in Section 2.4.3, sometimes the same XY coordinates

are repeated even though the aircraft has moved between the radar reports. Now in some cases the corrected track reports are substantially different from the original aircraft positions reported by the HCS. This situation implies that we, the experimenters, do not know the true position of the aircraft. Flights having a corrected track position report substantially different from the original position report were deleted (53 of these flights were excluded).

### 3.1.4 Truncated Flights

Often in the HCS track reports, several tracks reports are missing or have bad data. The position of the aircraft during the gap is unknown. If the gap is short, the missing track reports can be interpolated. When a large gap in the track data occurs, the track positions after the gap are discarded. Of the 452,976 radar track position reports, 15,756 or 3.6 % were discarded by truncating the tracks after missing or bad data.

Measurements of trajectory prediction errors were made on aircraft either already in the ZID airspace or approaching the ZID airspace and about to be in the airspace. Measurements were not made on aircraft after they left ZID airspace. That is, no measurements were made on the portions of the tracks outside ZID when the aircraft were flying away from the ZID airspace. 17.2% of the interpolated track reports were not used for this reason.

### 3.1.5 Aircraft Mix

The majority of the aircraft analyzed in this study are commercial airliners. The top 10 aircraft type account for 1358 of the 2506 flights, or 54.2 % of the total; the top 20 aircraft account for 1746 of the 2506 flights, or 69.7 % of the total. A histogram depicting the frequency of occurrence of the top 20 aircraft is provided in Figure 3.1-2. The aircraft are identified by their FAA type designators. Of the top 20 aircraft, 15 are jets and five are turboprops. Table 3.1-3 lists the aircraft manufacturers and model names of the top 10 aircraft. All of the top 10 aircraft are jets except for the EMB 120.

**Table 3.1-3: URET Scenario Aircraft**

| RANK | FAA TYPE IDENTIFIER | MANUFACTURER / MODEL | NUMBER OF FLIGHTS | PERCENTAGE OF FLIGHTS |
|---|---|---|---|---|
| 1 | DC9 | McDonnell-Douglas DC9 | 224 | 8.94 % |
| 2 | B727 | Boeing 727 | 186 | 7.42 % |
| 3 | B73B | Boeing 737-300/400/500 | 182 | 7.26 % |
| 4 | CARJ | Canadair Bombardier Regional Jet | 152 | 6.07 % |
| 5 | B757 | Boeing 757 | 143 | 5.71 % |
| 6 | MD80 | McDonnell- Douglas MD80 | 131 | 5.23 % |
| 7 | MD88 | McDonnell-Douglas MD88 | 122 | 4.87 % |
| 8 | B73A | Boeing 737-200 | 87 | 3.47 % |
| 9 | E120 | Embraer EMB 120 | 78 | 3.11 % |
| 10 | B737 | Boeing 737-200 | 53 | 2.11 % |

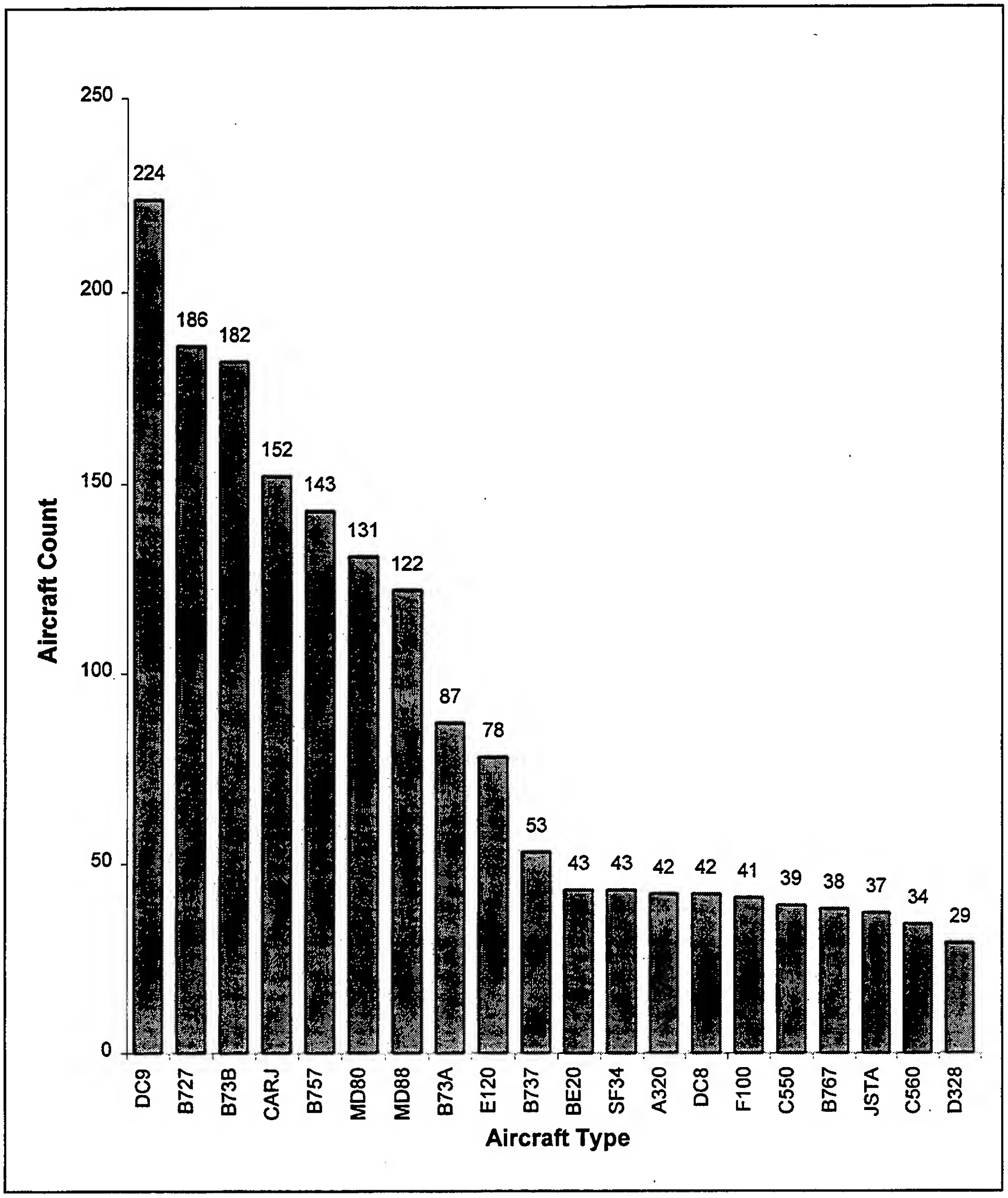


Figure 3.1-2: Top 20 Aircraft Frequency Histogram - ZID Data

## 3.2 Observations

This section presents observations made during analysis of the data, which provide detailed information about a specific aircraft flight in the URET study. These observations are included before the results so that the reader can better understand the methodology, and therefore better understand the statistics and data presented in Section 3.3. While each observation details a typical flight, the errors are not necessarily representative of common occurrences. Appendix C provides additional anomalous flights, which were selected to verify the methodology and to examine trajectory accuracy errors with URET.

### 3.2.1 URET1

In this example, a Boeing 737 commercial airliner departed Baltimore-Washington International (BWI) enroute for Chicago's Midway Airport (MDW). The filed route was J149 and the filed altitude was flight level (FL) 350. This route was an overflight through the northeast part of the ZID airspace. The filed route from BWI to MDW is shown in Figure 3.2-1 with selected waypoints illustrated as small circles.

#### 3.2.1.1 Track Data

The HCS acquired the radar track while the aircraft was in West Virginia (Washington Center, ZDC) on J149 heading west towards ZID. The HCS tracked the aircraft until it left ZID and entered the Chicago Center (ZAU) airspace heading towards Fort Wayne (FWA) on J149. The track data extends all the way to the Goshen VORTAC (GSH); however, no trajectory accuracy measurements were made after the aircraft left the ZID airspace. The track is shown in Figure 3.2-1. The track and the Flight Plan route are coincident.

The aircraft followed its filed route and filed altitude until a flight amendment was submitted to descend the aircraft from FL 350 to FL 310. After the amendment was submitted, there was an altitude hold at FL 350 for about a minute. Then the aircraft was cleared to the interim altitude of FL 330. The aircraft paused briefly at FL 330, and then, after being cleared, continued down to FL 310. The aircraft exited the ZID airspace at FL 310. Its Top of Descent (TOD) from FL 310 was outside of ZID. The altitude profile is shown in Figure 3.2-2.

The radar position reports supplied by HCS were reasonably consistent. Of the 244 position reports, 10 were defective and had to be fixed. The first track report had zero altitude and was discarded. There were five stationary position reports, which repeated the previous position report. The XYZ coordinates for these reports were replaced by interpolated values. There were four position reports which had zero altitude and one position report which was both stationary and had zero altitude. These reports were replaced by interpolated values as well.

#### 3.2.1.2 Trajectory Data

The track time and the time lines for the eight trajectories recovered for this aircraft are presented in Figure 3.2-3. The time line for the track is labeled "Track." The time lines for the trajectories are labeled with the trajectory's build time. The first three of these trajectories (the 45728, 45729, and 47218 trajectories) were built before the first track point at time 47230. The sample points for calculating the trajectory accuracy metrics are shown by arrows drawn from the track time line to the latest trajectory available at that sample time. The first sample time was 47270 (40 seconds after the first track point). This sample used the 47230 trajectory which was built with the first track point. Of these eight trajectories three were sampled: the 47230, 49062, and 49194 trajectories.

The three trajectories have been plotted in Figures 3.2-1 and 3.2-2. In the plan view (Figure 3.2-1), it can be seen that the trajectories are coincident with the filed route when the aircraft is approaching and within the ZID airspace. In the altitude profile plot (Figure 3.2-2), it can be seen that the trajectories differ from the track data near the TOD.

The trajectories plotted all start with a data point, which is sampled for the error measurements. Previous trajectory points have been discarded because they are not needed for the metric calculations. Up to two minutes of initial trajectory data may be discarded. For example, the first data point plotted for Trajectory 3 is at 49,310 seconds, although the trajectory was built at 49,194 seconds.

### 3.2.1.3 Metrics

Table 3.2-1 presents the trajectory metrics calculated for this aircraft. The longitudinal and lateral errors are in nautical miles; the vertical errors are in feet. As discussed in Section 2.5.1, a sample is taken 40 seconds after the start of track and then repeated each two minutes until either the track ends, the trajectory ends, or the track leaves the center. At each sample time, the distance between the track and trajectory was calculated at the current time and at look ahead times of 5, 10, 15, 20, and 30 minutes into the future. That is, measurements were made at look ahead times of 0, 300, 600, 900, 1200, 1500, and 1800 seconds. The metrics were not computed after time 49430 because the aircraft departed the ZID airspace at 49,550 seconds. The data in the table shows that both the longitudinal and lateral errors were small even at the higher look ahead times. The plot of the track and trajectory data in Figure 3.2-1 shows that the lateral errors are negligible. (The plot does not show the longitudinal errors.)

The vertical profile plot in Figure 3.2-2 shows that near the TOD there are differences in altitude between the predicted trajectories and the actual track flown. The first trajectory predicts an initial TOD at a time of 49,350 seconds and an initial Bottom of Descent (BOD) at an altitude of 31,000 feet and a time of 49,500 seconds. The actual (track) initial TOD was at 49,080 and the actual (track) initial BOD was at 49,370. The predicted TOD was updated to 49,100 by the second predicted trajectory when a Flight Plan Amendment was received. The second trajectory descended the aircraft to an interim altitude of 33,000 feet, held it there for four minutes, and then descended it to 31,000 feet starting at 49,420 reaching 31,000 feet at 49,500, and then it had a final descent, leaving 31,000 at 49,910. The track did not hold at 33,000 feet. The plot of the third trajectory flies the aircraft at 31,000 feet, coincident with the track, passing out of the ZID airspace before descending.

The inaccurate predictions of the TOD and the interim altitude hold produce errors in the predicted altitudes. Error measurements are made every 60 seconds (for some look ahead time). Measurements made at 49,190, 49,250, 49,310, 49,370, and 49,430 seconds show large altitude errors. All of the large altitude prediction errors except one are based on Trajectory 1. The other large altitude error is based on Trajectory 2. The errors have been listed in Table 3.2-1. The time of measurement is the sum of the sample time and the look ahead time. Figure 3.2-2 shows the differences in altitude between the track data and the predicted trajectories which produce these altitude errors.

The largest error (3629 feet) occurred at 49,370 when the aircraft had leveled off at 31,000 feet and it had been predicted to be just past its initial TOD, descending from 35,000 feet. This measurement was made for a look ahead of 15 minutes.

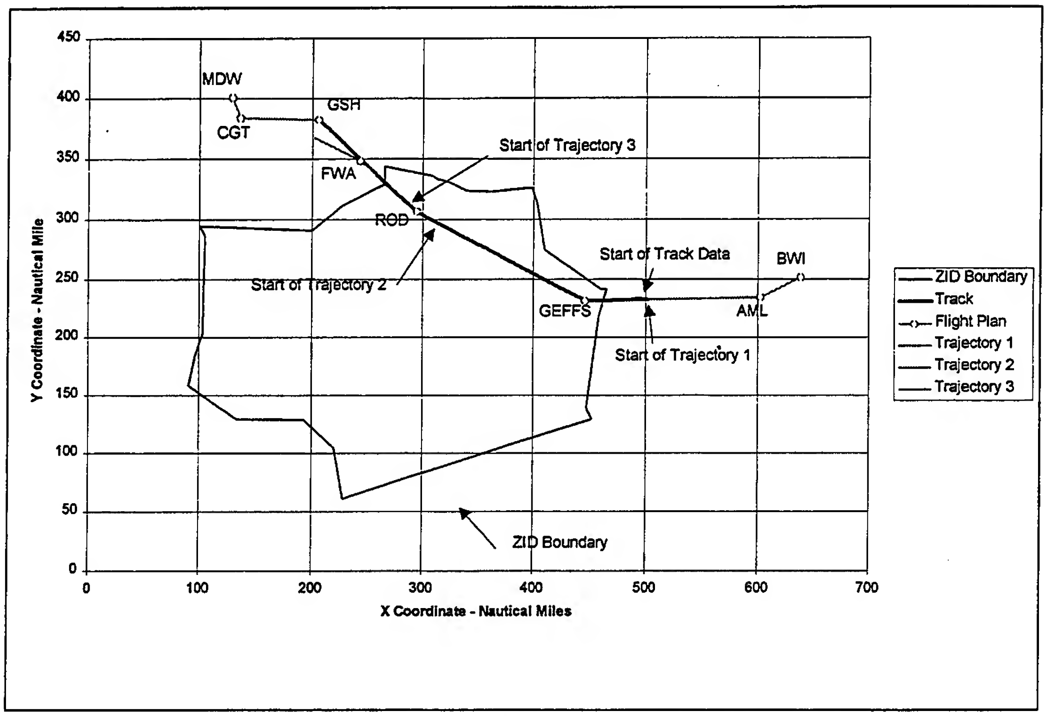


**Figure 3.2-1: Aircraft Track and Route**

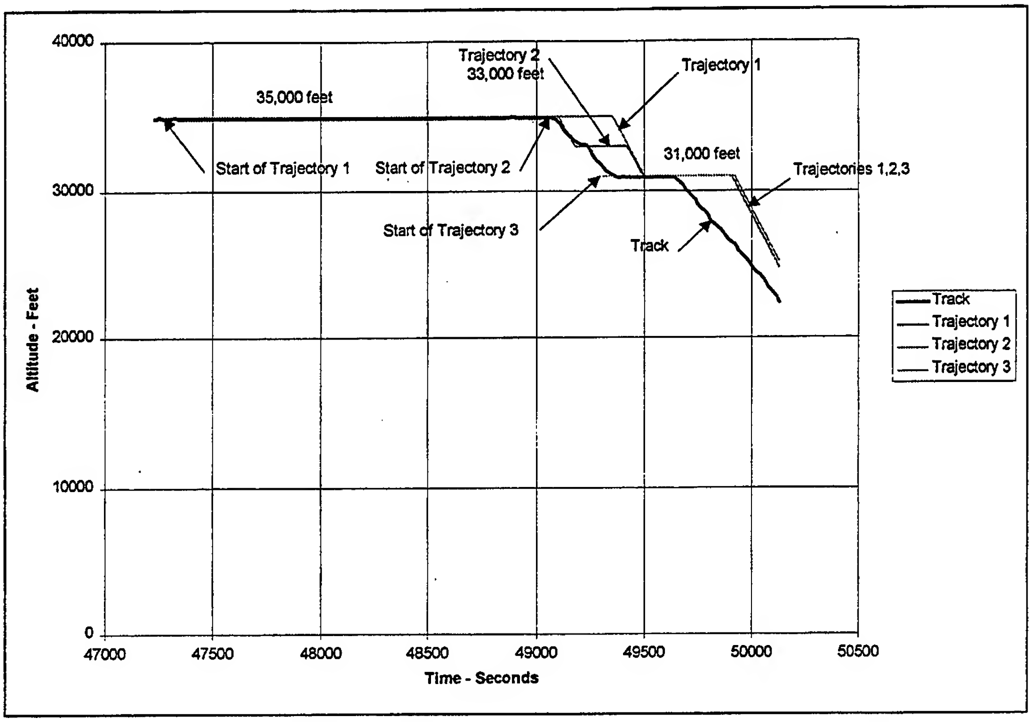


Figure 3.2-2: Altitude Vs. Time

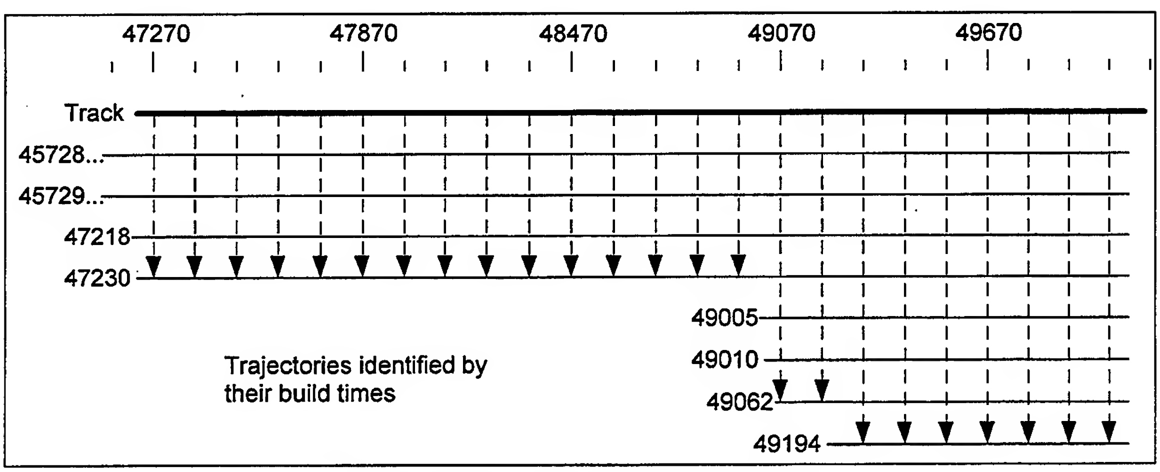


Figure 3.2-3: Sampled Trajectories

Table 3.2-1: Trajectory Metrics (1 of 2)[3]

| Sample Time | Traj No | Traj Build Time | Look Ahead Time | Long Error | Lat Error | Vert Error |
|---|---|---|---|---|---|---|
| 47270 | 1 | 47230 | 0 | -0.23 | -1.63 | -100.00 |
| | | | 300 | -0.50 | -0.12 | -100.00 |
| | | | 600 | -0.71 | 0.13 | -100.00 |
| | | | 900 | -0.85 | 0.18 | -100.00 |
| | | | 1200 | -0.60 | 0.21 | -100.00 |
| | | | 1500 | -1.16 | -0.09 | -100.00 |
| | | | 1800 | -0.52 | -0.25 | -100.00 |
| 47390 | 1 | 47230 | 0 | -0.38 | -0.42 | -100.00 |
| | | | 300 | -0.67 | -0.05 | -100.00 |
| | | | 600 | -0.81 | 0.09 | -100.00 |
| | | | 900 | -0.92 | 0.22 | -100.00 |
| | | | 1200 | -0.52 | 0.26 | -100.00 |
| | | | 1500 | -0.49 | -0.23 | -33.00 |
| | | | 1800 | -0.16 | -0.35 | -1733.00 |
| 47510 | 1 | 47230 | 0 | -0.46 | -0.11 | -100.00 |
| | | | 300 | -0.62 | 0.24 | -100.00 |
| | | | 600 | -0.90 | 0.14 | -100.00 |
| | | | 900 | -0.13 | 0.36 | -100.00 |
| | | | 1200 | -0.81 | -0.03 | -100.00 |
| | | | 1500 | -0.55 | -0.09 | -100.00 |
| | | | 1800 | 0.54 | -0.14 | -3400.00 |
| 47630 | 1 | 47230 | 0 | -0.56 | -0.09 | -100.00 |
| | | | 300 | -0.66 | 0.07 | -100.00 |
| | | | 600 | -0.91 | 0.12 | -100.00 |
| | | | 900 | -0.55 | 0.30 | -100.00 |
| | | | 1200 | -1.08 | -0.19 | -100.00 |
| | | | 1500 | -0.39 | -0.28 | -956.00 |
| | | | 1800 | 1.03 | -0.27 | -2061.60 |
| 47750 | 1 | 47230 | 0 | -0.70 | 0.12 | -100.00 |
| | | | 300 | -0.84 | 0.16 | -100.00 |
| | | | 600 | -0.85 | 0.11 | -100.00 |
| | | | 900 | -0.54 | 0.13 | -100.00 |
| | | | 1200 | -0.44 | -0.20 | -100.00 |
| | | | 1500 | -0.41 | -0.39 | -2300.00 |
| 47870 | 1 | 47230 | 0 | -0.71 | 0.13 | -100.00 |
| | | | 300 | -0.85 | 0.18 | -100.00 |
| | | | 600 | -0.60 | 0.21 | -100.00 |
| | | | 900 | -1.16 | -0.09 | -100.00 |
| | | | 1200 | -0.52 | -0.25 | -100.00 |
| | | | 1500 | 0.74 | -0.20 | -3629.08 |
| 47990 | 1 | 47230 | 0 | -0.81 | 0.09 | -100.00 |
| | | | 300 | -0.92 | 0.22 | -100.00 |
| | | | 600 | -0.52 | 0.26 | -100.00 |
| | | | 900 | -0.49 | -0.23 | -33.00 |
| | | | 1200 | -0.16 | -0.35 | -1733.00 |
| | | | 1500 | 1.27 | -0.10 | -400.57 |

[3] In this chart, longitudinal and lateral error are reported in hundredths of nautical miles, and the vertical error is reported in hundredths of feet. The precision of the input HCS altitude data is reported to the nearest 100 feet, the apparent difference is simply an artifact of the track report processing.

Table 3.2-1: Trajectory Metrics (2 of 2)

| Sample Time | Traj No | Traj Build Time | Look Ahead Time | Long Error | Lat Error | Vert Error |
|---|---|---|---|---|---|---|
| 48110 | 1 | 47230 | 0 | -0.90 | 0.14 | -100.00 |
| | | | 300 | -0.13 | 0.36 | -100.00 |
| | | | 600 | -0.81 | -0.03 | -100.00 |
| | | | 900 | -0.55 | -0.09 | -100.00 |
| | | | 1200 | 0.54 | -0.14 | -3400.00 |
| 48230 | 1 | 47230 | 0 | -0.91 | 0.12 | -100.00 |
| | | | 300 | -0.55 | 0.30 | -100.00 |
| | | | 600 | -1.08 | -0.19 | -100.00 |
| | | | 900 | -0.39 | -0.28 | -956.00 |
| | | | 1200 | 1.03 | -0.27 | -2061.60 |
| 48350 | 1 | 47230 | 0 | -0.85 | 0.11 | -100.00 |
| | | | 300 | -0.54 | 0.13 | -100.00 |
| | | | 600 | -0.44 | -0.20 | -100.00 |
| | | | 900 | -0.41 | -0.39 | -2300.00 |
| 48470 | 1 | 47230 | 0 | -0.60 | 0.21 | -100.00 |
| | | | 300 | -1.16 | -0.09 | -100.00 |
| | | | 600 | -0.52 | -0.25 | -100.00 |
| | | | 900 | 0.74 | -0.20 | -3629.08 |
| 48590 | 1 | 47230 | 0 | -0.52 | 0.26 | -100.00 |
| | | | 300 | -0.49 | -0.23 | -33.00 |
| | | | 600 | -0.16 | -0.35 | -1733.00 |
| | | | 900 | 1.27 | -0.10 | -400.57 |
| 48710 | 1 | 47230 | 0 | -0.81 | -0.03 | -100.00 |
| | | | 300 | -0.55 | -0.09 | -100.00 |
| | | | 600 | 0.54 | -0.14 | -3400.00 |
| 48830 | 1 | 47230 | 0 | -1.08 | -0.19 | -100.00 |
| | | | 300 | -0.39 | -0.28 | -956.00 |
| | | | 600 | 1.03 | -0.27 | -2061.60 |
| 48950 | 1 | 47230 | 0 | -0.44 | -0.20 | -100.00 |
| | | | 300 | -0.41 | -0.39 | -2300.00 |
| 49070 | 2 | 49062 | 0 | -0.44 | -0.25 | -100.00 |
| | | | 300 | 0.09 | -0.20 | -2033.00 |
| 49190 | 2 | 49062 | 0 | -0.33 | -0.35 | 267.00 |
| | | | 300 | 0.49 | -0.10 | -238.11 |
| 49310 | 3 | 49194 | 0 | 0.05 | -0.14 | 600.00 |
| 49430 | 3 | 49194 | 0 | 0.51 | -0.27 | -100.00 |

## 3.3 Results

After running URET Delivery 3A with the 7.5 hour scenario file described in Section 3.1, a total of 16,631 trajectories were sampled out of 40,894 trajectories. The sampled trajectories were from 2436 flights. Therefore, each one of these flights on average had 6.8 trajectories analyzed. The average duration of these trajectories is 57 minutes with standard deviation of 39 minutes. The sampling process reduced the trajectory to the portion where both HCS track data and the predicted trajectory overlap in time, so the duration of the trajectory actually analyzed was reduced to approximately 29 minutes on average, with a standard deviation of 18 minutes.

To set the context of the study as defined in Section 2.6.2.1, the counts of the event areas illustrated in Figure 2.6-1 are listed in Table 3.3-1 below. Referring to Figure 2.6-1, the ratio of area "a" to the sum of areas "a" and "c" defines URET's fraction of valid flights with sampled trajectory prediction. For URET, 97.2 percent of the valid aircraft flights had sampled trajectory prediction.

**Table 3.3-1: Valid Track and Trajectory Counts for URET Scenario**

| | Valid HCS Flight Data | Insufficient Valid HCS Flight Data | Total Flights With Trajectories |
|---|---|---|---|
| Trajectory | 2436 (a) | 1296 (b) | 3732 (a +b) |
| Insufficient Trajectory | 70 (c) | | |
| Total Valid Flights | 2506 (a + c) | | |

As defined in Section 2.6.2.2, another statistic useful in setting the context of the study estimates the trajectory prediction coverage over the track time analyzed. For URET, each analyzed flight had an average of 96.6 percent of prediction coverage with a standard deviation of 6.1 percent. Referring to Figure 3.3-1 and the Quantiles in Table 3.3-2, the distribution decreases very sharply, making a narrow 95 percent confidence interval around the mean between 96.4 to 96.9. The maximum ratio of prediction coverage for URET was 99.4 percent and the minimum was 2.9 percent.

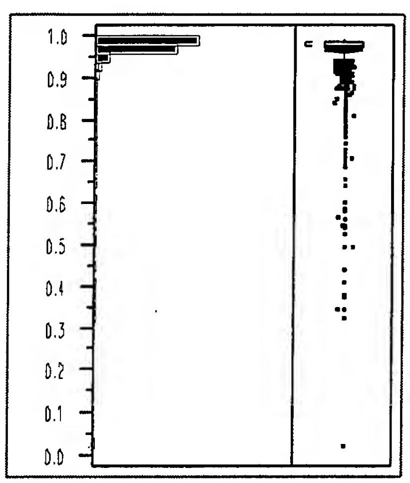


**Figure 3.3-1: URET's Distribution of Ratio of Coverage Statistic**

**Table 3.3-2: Quantile Table of Ratio of Prediction Coverage**

| Quantile Label | Percentile | Value |
|---|---|---|
| maximum | 100.00% | 0.99434 |
| | 99.50% | 0.99246 |
| | 97.50% | 0.99024 |
| | 90.00% | 0.98813 |
| quartile | 75.00% | 0.98491 |
| median | 50.00% | 0.97938 |
| quartile | 25.00% | 0.97037 |
| | 10.00% | 0.94964 |
| | 2.50% | 0.84657 |
| | 0.50% | 0.5 |
| minimum | 0.00% | 0.02913 |

As described in Section 2.6.2.3, another descriptive value that defines the context of the analysis is the age of the trajectory at the look ahead time of zero. For URET, trajectories are built when the HCS track positions are outside thresholds (referred to as conformance boxes) around the trajectory centerline, when certain messages are received from the HCS, or every 20 minutes. This study's sampled URET trajectories have an average trajectory age of approximately four minutes with a standard deviation of 5.1 minutes.

As discussed above, URET builds trajectories every 20 minutes maximum and often earlier depending on the HCS track positions. The build time in seconds combined with the aircraft identifier string and HCS CID should uniquely represent a particular trajectory. However, there are instances that an aircraft has multiple trajectories with common build times. This is an anomaly of URET's data recording software, which runs in parallel to the URET processes but apparently has a lower priority on machine resources. The anomaly occurs when the data recorder builds up a queue in its processing and gets behind the data being stored in the URET databases. If more than one trajectory is in the queue for a particular flight, the time stamps of the trajectories utilized for the build time can get duplicated creating common trajectory build times. The solution applied was to add one second to the trajectory build time (i.e. sequentially by recording order) in these instances. For the scenario in this study, around 10 percent of the 40,894 URET trajectories needed this adjustment. Once again, the adjustment was only to the build time and was only changed by one second.

The actual trajectory metrics and sampling process is defined in Section 2.5.1. For this 7.5 hour ZID scenario, 138,532 samples were taken against the 16,631 trajectories discussed above. Each sample consisted of spatial prediction error measurements including horizontal error, lateral error, longitudinal error, and vertical error. These measures are reported as a function of different look ahead times from zero to 30 minutes in the future, so the trajectory prediction performance includes the spatial prediction errors partitioned by look ahead time. As a review, look ahead time is the predicted time into the future measured from the sample start time for that particular flight. In this study increments of five minutes were used up to a look ahead time of 30 minutes into the future. In other words, if the flight had both a sampled trajectory and sufficient HCS

track reports for the full range of time overlap, error measurements would be calculated at zero, five, 10, 15, 20, 25 and 30 minutes into the future.

Table 3.3-3 lists the types of statistical analyses that were performed on each of the identified factors. The analyses include either descriptive statistics in which simple tables are presented, inferential statistics in which hypothesis testing of the means and variances were performed, or both. This table also lists whether graphical information was presented with references to the appropriate section number. Inferential statistics and graphical plots (i.e. histograms and quantile tables) were calculated for a subset of the available look ahead times, including zero, 600, 1200, and 1800 seconds. The signed values of the error metrics (e.g. average lateral error) were used for these more exhaustive inferential techniques, since the sample mean acts as a measure of the bias of the trajectory predictions and the standard deviation as a measure of the uncertainty. The absolute value statistics (e.g. average absolute value of lateral error), which are also a useful measure of the uncertainty, have been included in the descriptive statistics reported in Appendix A.1.

**Table 3.3-3: URET Analysis Summary**

| Factor For Samples at All Altitudes / Above FL180 | Descriptive Statistics | Inferential Statistics | Histograms / Quantiles | Section Number |
|---|---|---|---|---|
| Look Ahead Time | Yes | Yes | Yes | 3.3.1 |
| Flight Type | Yes | Yes | No | 3.3.2 |
| Phase of Flight Horizontal | Yes | Yes | No | 3.3.3 |
| Phase of Flight Vertical | Yes | Yes | No | 3.3.4 |

## 3.3.1 Analysis of Look ahead time on Trajectory Accuracy

The main factor analyzed in this study was look ahead time, defined in Section 2.2.3.3. One would expect look ahead time to have a statistically significant effect on performance, but the magnitude of the effect is also of interest. A complete table of the spatial prediction error statistics are presented at the look ahead times of zero, 300, 600, 900, 1200, 1500, and 1800 seconds (i.e. zero to 30 minutes) in Appendix A.1. The focus of the following analysis is on the signed error for lateral, longitudinal, horizontal, and vertical errors at the look ahead times of zero, 600, 1200, and 1800 seconds. This analysis includes an example set and summary results of several tables of statistical information provided by the SAS-JMP Software package (SAS Institute, 1995). They are used to evaluate the error data categorized by look ahead time and in the later sections by horizontal and vertical phase of flight. Complete tables for the URET data are provided in Appendix A.1. The tables present test results for unequal variance including the Levene Test and the Welch Anova Test. They also include a pairwise means comparison, referred to as the Tukey-Kramer Honestly Significant Difference (HSD) Test. Graphical plots present a comparison of means with a quantile box, a plot of the means at look ahead time versus error, and a plot of means using the Tukey-Kramer criteria.

### 3.3.1.1 Samples at all altitudes

The sample variance of the horizontal error from the four look ahead times are compared first by a Levene Statistical test (Neter, 1996). Referring to Table 3.3-4, this statistical test determines if the hypothesis of equal variances can be rejected. The hypothesis can be rejected in this case, since the variances are significantly different. From Table 3.3-4, the variance of horizontal error is increasing as the look ahead time increases.

**Table 3.3-4: Tests for Equal Variances and Tests for Equal Means**

| Tests that the Variances are Equal (Horizontal Error)[4] | | | | |
|---|---|---|---|---|
| Level (seconds) | Count | Std Dev (nm) | MeanAbsDif To Mean (nm) | MeanAbsDif To Median (nm) |
| 0 | 35928 | 1.08 | 0.71 | 0.69 |
| 600 | 23964 | 5.47 | 3.66 | 3.36 |
| 1200 | 13836 | 8.89 | 5.82 | 5.39 |
| 1800 | 6444 | 10.90 | 7.01 | 6.49 |
| Test | F Ratio | Deg of Freedom | DF Den | Prob>F |
| Levene | 7382.12 | 3 | 80168 | 0.0000 |
| Welch Anova testing Means Equal, allowing Std's Not Equal | | | | |
| | F Ratio | Deg of Freedom | DF Den | Prob>F |
| | 8172.26 | 3 | 18809 | 0.0000 |

Next, the sample mean for each look ahead time is compared. Referring to Table 3.3-4, the Welch test is applied which compares distributions with different variances and sample sizes. It tests whether all the group means are equal. For the horizontal error at different look ahead times, the Welch Test provides evidence to reject the hypothesis that these mean errors are equal. In Figure 3.3-2, diamonds are drawn around each mean representing the 95 percent confidence interval (in this case, the diamonds are flat and look more like heavy lines due to the large range between the group means). These confidence intervals show an increase in the average horizontal error from zero to 1800 seconds look ahead time of approximately 9.0 nautical miles, from 1.2 nautical miles to 10.2 nautical miles.

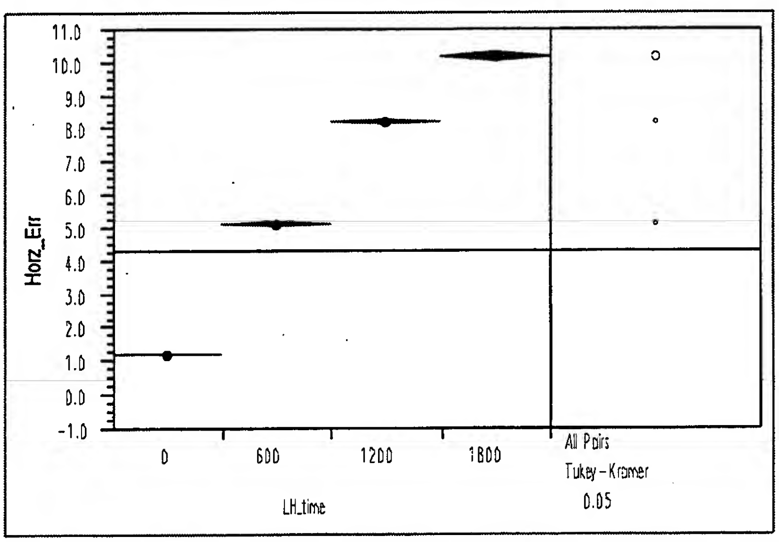


**Figure 3.3-2: Sample Mean Comparison of Horizontal Error at Four Look Ahead Times[5]**

[4] Mean Absolute difference to mean and median are intermediate calculations in the Levene Test described in Appendix A.0.

[5] Normally, the height of the diamond is the length of the confidence interval and the width is proportional to the sample size. In this study, the width has been set equal for all sample sizes.

The lower portion of Table 3.3-5 presents the results of a third statistical test, called the Tukey-Kramer Test, that compares all pairs of means and holds the Type I error at 0.05 for the entire test. It has the exact Type I error if the sample sizes are equal, and is conservative if they are not, which is the case in this study. The horizontal error at the four look ahead times is significantly different between all pairs. The Tukey-Kramer Test provides a distance referred to as the Least Significant Difference (LSD)[6] that can be subtracted from the absolute difference of each pair of means. If the result is positive, the absolute difference of the means is greater than LSD, and the pair of means is significantly different. If the result is negative, the LSD is greater, and the pair is not significantly different. The upper portion of Table 3.3-5 lists the pairwise differences of the sample means for the various look ahead times. All these pairwise comparisons of the means of the horizontal error at the different look ahead times were significant.

The right side of Figure 3.3-2 presents a graphical form of the Tukey-Kramer Test. Too small to be drawn in some cases, it constructs circles around the sample means with a diameter approximately equal to the 95 percent confidence interval. However, this interval is expanded to account for the comparison of all pairs. In short, if the circles overlap the means are not considered significantly different; if they do not overlap, the means are considered significantly different. The circles drawn in Figure 3.3-2 are not overlapping at all, illustrating the numerical results that all the means are different.

**Table 3.3-5: Statistical Comparison of All Means (Horizontal Error)**

| Means Comparisons | | | | |
|---|---|---|---|---|
| Dif=Mean[i]-Mean[j] | 1800 | 1200 | 600 | 0 |
| 1800 | 0.00 | 1.92 | 5.06 | 8.96 |
| 1200 | -1.92 | 0.00 | 3.14 | 7.04 |
| 600 | -5.06 | -3.14 | 0.00 | 3.90 |
| 0 | -8.96 | -7.04 | -3.90 | 0.00 |
| Comparisons for all pairs using Tukey-Kramer HSD | | | | |
| q* = 2.56909 | Alpha= 0.05 | | | |
| Abs(Dif)-LSD | 1800 | 1200 | 600 | 0 |
| 1800 | -0.26 | 1.70 | 4.85 | 8.76 |
| 1200 | 1.70 | -0.18 | 2.98 | 6.90 |
| 600 | 4.85 | 2.98 | -0.13 | 3.78 |
| 0 | 8.76 | 6.90 | 3.78 | -0.11 |
| Positive values show pairs of means that are significantly different. | | | | |

[6] LSD is proportional to the square root of the sum of the squared product of q* and the standard error of both means being compared. The q* value is a quantile similar to the t value of a Student t distribution but expanded to account for the alpha being held for the entire set of comparisons (SAS Institute, 1995).

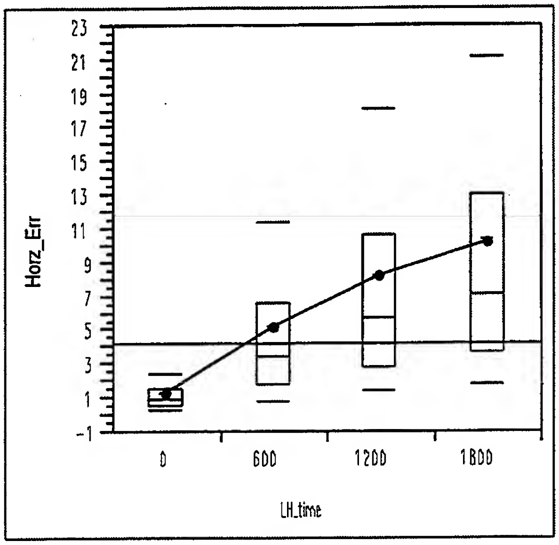


**Figure 3.3-3: Quantile / Mean Comparison of Horizontal Error Vs. LH**

In summary, the mean horizontal error is statistically significant at the look ahead times of zero, 600, 1200, and 1800 seconds. Referring to Figure 3.3-3, the sample means are also increasing as the look ahead time (LH) increases, ranging from a sample mean of 1.2 nautical miles at look ahead zero to 10.2 at 1800 seconds (i.e. 30 minutes). The mean of all observations is drawn as a horizontal line across the entire plot. The median is also increasing from 0.96 nautical miles at zero look ahead time to 7.1 at 1800 seconds. The horizontal lines in Figure 3.3-3's boxes correspond to the 10, 25, 50, 75, and 90 percentiles of the distribution of the sampled horizontal errors, respectively[7]. Tested statistically with the Levene Test earlier, the box ranges illustrate that the spread of the horizontal error is also increasing as the look ahead time increases.

The analysis continues by examining the lateral, longitudinal, and vertical errors using the same methods described for the horizontal error. The results are summarized in Table 3.3-6 and the means comparisons of the lateral, longitudinal and vertical errors are shown in Figures 3.3-4 through 3.3-6. The descriptive statistics of the absolute values of the four errors are tabulated in Appendix A.1.

[7] The percentiles illustrated in the Figure 3.3-3 as horizontal lines and box ends are described in detail in Appendix A.0.

**Table 3.3-6: Statistical Results LH 0-30 minutes for All Altitudes**

| Error Type | Levene Test | Welch Test | Tukey-Kramer[8] | Observations |
|---|---|---|---|---|
| Horizontal | Yes | Yes | Yes – all | Mean and variance increases as look ahead time (LH) increases. Means range from 1.2 to 10.2 nautical miles (nm). |
| Lateral | Yes | Yes | Yes-3of6 | Mean at LH 0 different from others. Mean and variance increase as LH increases. Means range from -0.02 to -0.22 nm. |
| Longitudinal | Yes | Yes | Yes – 5of6 | Both mean and variance different. Only means at LH 1200 versus 1800 not different. Means increase in value as LH increases, ranging from –0.02 to 0.88 nm. |
| Vertical | Yes | Yes | Yes –all | Mean ranges from 49 to –327 feet. Mean (becomes more negative) and variance increase as LH increases. |

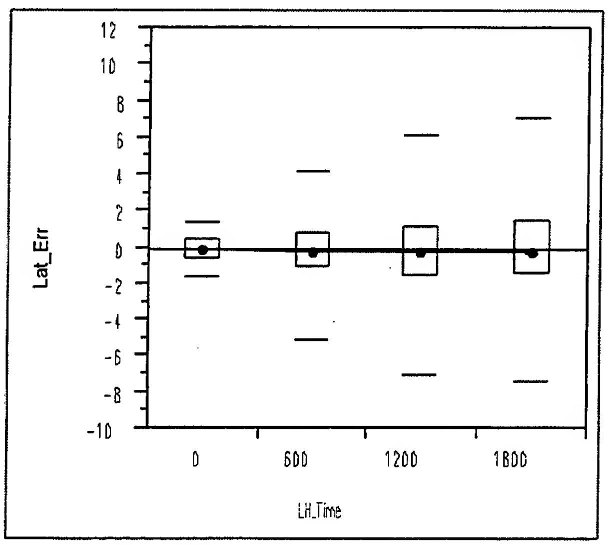


**Figure 3.3-4: Quantile / Mean Comparison of Lateral Error Vs. LH**

[8] In this table, "yes" means test provides evidence to reject hypothesis that means or variances are equal. "Yes-all" means Tukey-Kramer found all pairs of means not equal, and "Yes-1of6" means it found only 1 pair of means not equal in 6 combinations of pairwise comparisons.

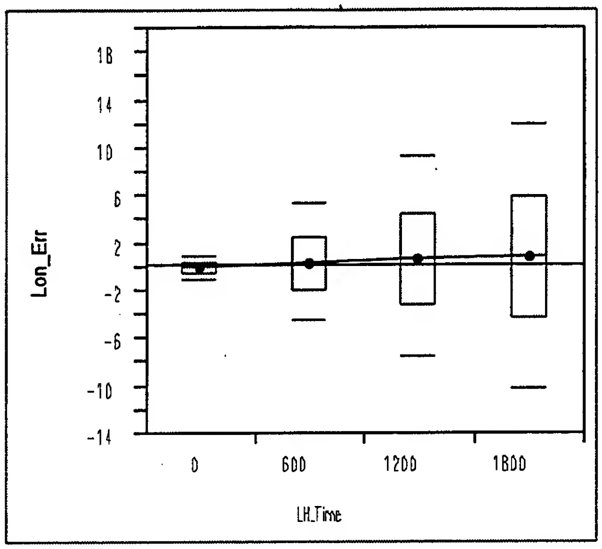


**Figure 3.3-5: Quantile / Mean Comparison of Longitudinal Error Vs. LH**

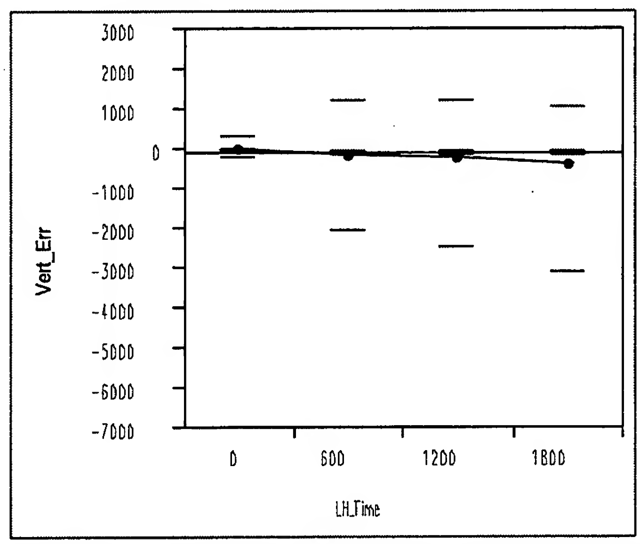


**Figure 3.3-6: Quantile / Mean Comparison of Vertical Error Vs. LH**

### 3.3.1.2 Samples at altitudes above 18,000 feet

For samples at altitudes above 18,000 feet only, the results are summarized in Table 3.3-7. The detailed histograms and statistical tables are located in Appendix A.1.

**Table 3.3-7: Statistical Results LH 0-30 minutes Above 18,000 feet**

| Error Type | Levene Test | Welch Test | Tukey-Kramer | Observations |
|---|---|---|---|---|
| Horizontal | Yes | Yes | Yes – all | Mean and variance increases as LH increases. Means range from 1.1 to 10.6 nm and standard deviation ranges from 0.94 to 11.5 nm. |
| Lateral | Yes | Yes | Yes-3of6 | Only LH 0 different from others. Variance increases as LH increases. Means range from –0.02 to -0.44 nm. |
| Longitudinal | Yes | Yes | Yes – 5of6 | Mean LH 1200 versus 1800 not different. Mean and variance increase with LH. |
| Vertical | Yes | Yes | Yes – 5of6 | Mean ranges from 39 to -180 feet. Variance increases with LH. T-K Test shows no difference between means at 0 and 600 seconds LH. |

### 3.3.1.3 Discussion of the effect of look ahead time

In general, look ahead time does have a significant effect on each sample mean and increases as the look ahead time increases. For horizontal error, the sample means increase over 10 nautical miles from zero to 1800 seconds (i.e. 30 minutes) look ahead time. Since lateral and longitudinal errors are exact orthogonal components of the horizontal error, it is interesting to note that the dominant source of the increase in horizontal error with look ahead time is the longitudinal error. Longitudinal error increases around one nautical mile with look ahead time zero to 30 minutes, while the absolute longitudinal error does increase around seven nautical miles. The lateral error increases by around a 0.25 nautical mile with look ahead time, and its absolute error increases by around four nautical miles. Statistically the lateral error only shows a difference between look ahead zero and the others, while longitudinal shows a difference in practically all look ahead times except between 1200 and 1800 seconds. Therefore, most of the error affecting an increase in the horizontal dimension as look ahead time increases is dominated by the longitudinal component.

Another aspect of the longitudinal error is the direction of the increase as look ahead time increases. On average, longitudinal error becomes more positive as look ahead increases. The aircraft on average are getting ahead of the prediction or conversely the predictions are getting behind the aircraft. The specific reasons for this will have to be left for future study but could be related to anything from URET's aircraft modeling parameters to weather profiles of the particular day analyzed.

The vertical error also shows a significant difference between sample means, but the mean differences like the lateral error are relatively small, ranging around 300 to 400 feet for all altitudes and around 200 feet for samples above 18,000 feet. For the vertical error, the sample means may be relatively small, but the variance increases dramatically with a standard deviation

ranging from around 600 to 2300 feet. In other words, the central tendency of the vertical error may not change dramatically, but the spread increases significantly as look ahead time increases.

In general, the variance increases significantly for all the error variables in both horizontal and vertical dimensions. For horizontal error, the standard deviation increases over nine nautical miles from zero to 1800 look ahead time. This range of nine nautical miles holds true for lateral and longitudinal errors as well. The spread of the errors increases as the look ahead time increases.

The differences between the trajectory prediction errors from samples at all altitudes versus above 18,000 feet are small, and they lead to the same conclusions about the distributions.

### 3.3.2 Analysis of Flight Type on Trajectory Accuracy

Flight type is determined by examining the origin and destination airports in a flight plan. The flight type includes four possible levels referred to as overflight, departure, arrival, and internal. Overflight is an aircraft whose origin and destination airports are outside the particular center's airspace, ZID in this case. Departures leave an airport inside the center, and arrivals land at an airport inside the center. The internals include flights that have both origin and destination airports inside the center.

The analysis that follows examines whether the means of the trajectory prediction errors of the different flight types are significantly different at the four look ahead times of 0, 600, 1200, and 1800 seconds. This analysis focuses on these four look ahead times and flight types against the signed lateral, longitudinal, vertical, and horizontal errors. Appendix A.1 contains a more complete set of look ahead times and also includes the descriptive statistics on the unsigned or absolute values of the errors. Figures 3.3-7 through 3.3-10 plot the means as a function of look ahead time (LH) where OVR denotes overflights, ARR denotes arrivals, DEP denotes departures, and INR denotes internals.

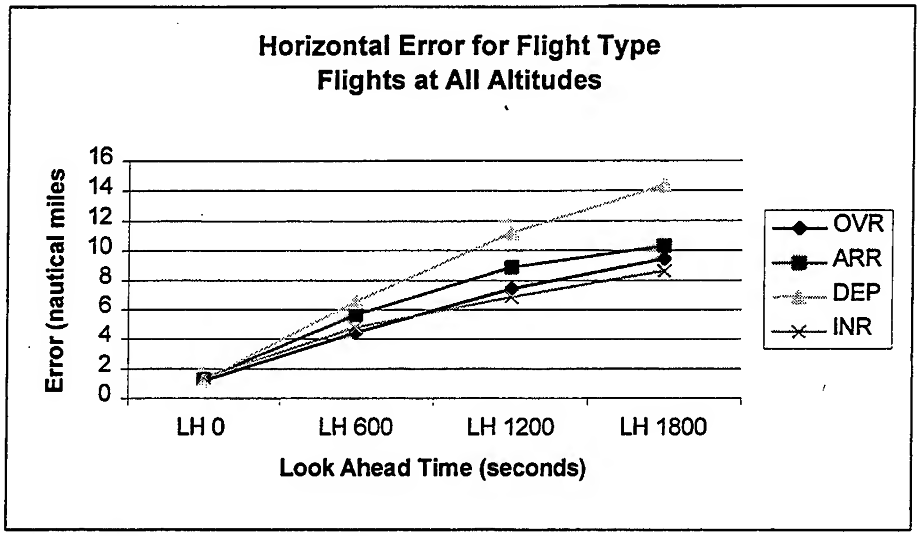


**Figure 3.3-7: Sample Means for Horizontal Error per Flight Type and LH**

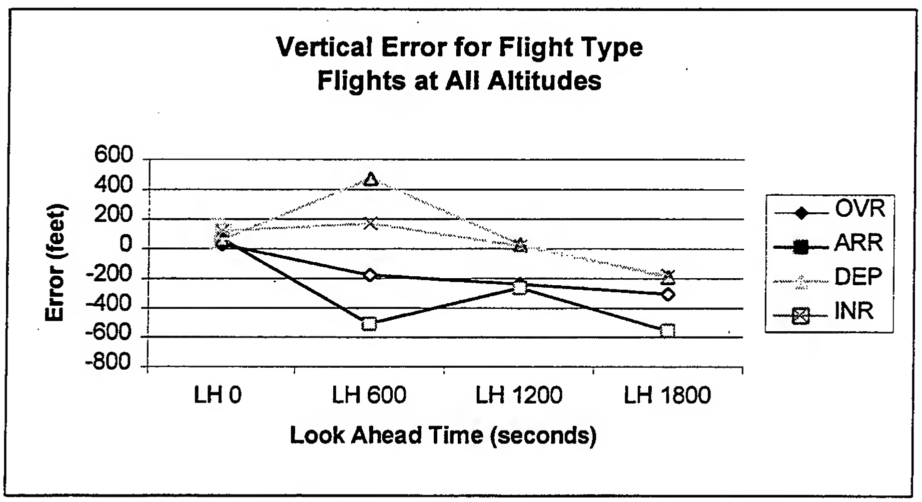


**Figure 3.3-8: Sample Means for Vertical Error per Flight Type and LH**

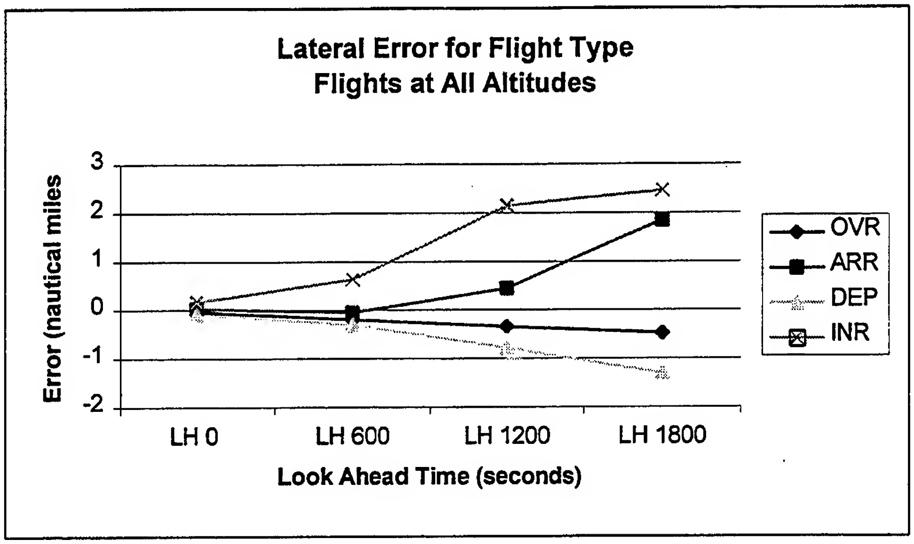


**Figure 3.3-9: Sample Means for Lateral Error per Flight Type and LH**

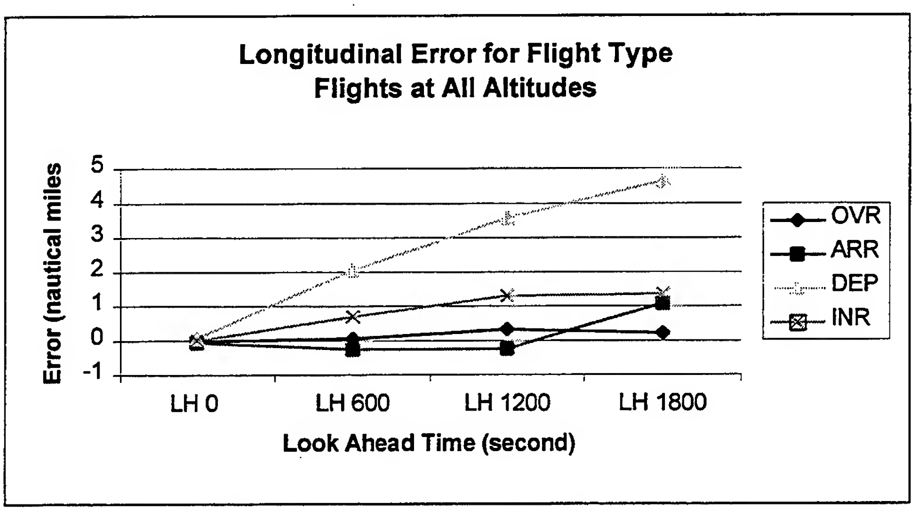


**Figure 3.3-10: Sample Means for Longitudinal Error per Flight Type and LH**

### 3.3.2.1 Samples at all altitudes

Statistical results for all altitudes are summarized in Table 3.3-8. The detailed histograms and statistical tables are located in Appendix A.1.

**Table 3.3-8: Statistical Results LH 0-30 minutes at All Altitudes**

| Error Type | Look ahead Time | Levene Test | Welch Test | Tukey-Kramer | Observations |
|---|---|---|---|---|---|
| Horizontal | 0 | Yes | Yes | Yes-5of6 | T-K Test shows arrivals and internals are not significantly different. |
| Lateral | 0 | Yes | Yes | Yes-5of6 | Only overflights versus departures are not different. |
| Long. | 0 | Yes | Yes | Yes-3of6 | Only internals are not significantly different from the others. |
| Vertical | 0 | Yes | Yes | Yes-3of6 | Only overflights are different than the other three flight types. Overflights have less vertical error with a sample mean of 32 feet compared to a range of 61-121 feet. |
| Horizontal | 600 | Yes | Yes | Yes-5of6 | T-K shows overflights and internals are not significantly different. |
| Lateral | 600 | Yes | Yes | Yes-2of6 | Only internals versus either overflights or departures are significantly different. |
| Long. | 600 | Yes | Yes | Yes-5of6 | Only internals versus overflights are not different. |
| Vertical | 600 | Yes | Yes | Yes-all | Although all the means are different, arrivals and departures are around 500 feet in error on average and overflights and internals are around 200 feet. |
| Horizontal | 1200 | Yes | Yes | Yes-5of6 | T-K shows overflights and internals are not significantly different. |
| Lateral | 1200 | Yes | Yes | Yes-5of6 | Only overflights versus departures are not significantly different. |
| Long. | 1200 | Yes | Yes | Yes-4of6 | Only internals versus either overflights or arrivals are not significantly different. |
| Vertical | 1200 | Yes | Yes | Yes-2of6 | Departures versus overflights or arrivals are significantly different. |
| Horizontal | 1800 | Yes | Yes | Yes-3of6 | T-K shows only departures are significantly different to the other types. |
| Lateral | 1800 | Yes | Yes | Yes-3of6 | Departures versus either arrivals or internals and arrivals versus overflights are significantly different. |
| Long. | 1800 | Yes | Yes | Yes-2of6 | Departures versus arrivals and overflights are significantly different. |
| Vertical | 1800 | Yes | Yes | Yes-2of6 | All means negative ranging from 200 to 600 feet error. T-K shows arrivals versus overflights and departures are different. |

### 3.3.2.2 Samples at altitudes above 18,000 feet

Statistical results for altitudes above 18,000 feet are summarized in Table 3.3-9. The detailed histograms and statistical tables are located in Appendix A.1.

**Table 3.3-9: Statistical Results LH 0-30 minutes Above 18,000 feet**

| Error Type | Look ahead Time | Levene Test | Welch Test | Tukey-Kramer | Observations |
|---|---|---|---|---|---|
| Horizontal | 0 | Yes | Yes | Yes-4of6 | T-K Test shows internals versus overflights and arrivals are not different. |
| Lateral | 0 | Yes | Yes | Yes-1of6 | Only arrivals versus departures are significantly different. |
| Long. | 0 | Yes | Yes | Yes-3of6 | Only internals are not different from the other flight types. |
| Vertical | 0 | Yes | Yes | Yes-4of6 | T-K shows departures versus overflights and arrivals are significantly different. Overflights and departures have less error with around 32 feet on average. |
| Horizontal | 600 | Yes | Yes | Yes-3of6 | Only internals vs. others are not different. |
| Lateral | 600 | Yes | Yes | Yes-1of6 | Only overflights versus departures are significantly different. |
| Long. | 600 | Yes | Yes | Yes-5of6 | Only internals versus departures are not different. |
| Vertical | 600 | Yes | Yes | Yes-all | All means are different ranging from around -168 to 3700 feet. |
| Horizontal | 1200 | Yes | Yes | Yes-3of6 | Only internals vs. others are not different, based on one sample so inconclusive. |
| Lateral | 1200 | Yes | Yes | Yes-3of6 | All are different except internals which are based on one sample. |
| Long. | 1200 | Yes | Yes | Yes-2of6 | Departures versus overflights and arrivals are different. Only one sample for internals. |
| Vertical | 1200 | Yes | Yes | Yes-all | All means are significantly different, but internals inconclusive with one sample. |
| Horizontal | 1800 | Yes | Yes | Yes-2of3 | No internal samples. Departures differ from overflights and arrivals. |
| Lateral | 1800 | Yes | Yes | Yes-All | No internal samples. All means and variance different. |
| Long. | 1800 | Yes | Yes | Yes-2of3 | No internal samples. Only overflights and arrivals are not different. |
| Vertical | 1800 | Yes | Yes | Yes-2of3 | No internal samples. Arrivals differ from overflights and departures. |

### 3.3.2.3 Discussion of the effect of flight type

In general, flight type did have a significant effect on the performance of the trajectory predictions but not nearly as much as the look ahead time. In general, overflights performed the best at the lower look ahead times for all samples, but internals and overflights did not have significant differences at the larger look ahead times for all altitude samples. Any conclusions on internals for the samples above 18,000 feet are inconclusive since the sample sizes were small or

nonexistent. For horizontal error, departures seem to have the largest error, ranging from 1.2 to 14.4 nautical miles, as look ahead time increases. For vertical error, the same is true for arrivals. That is, for arrivals the vertical error increases as look ahead time increases the most from around 60 to –550 feet on average.

There were relatively small sample sizes for internals at the larger look ahead times. The samples are taken along a trajectory for a look ahead time window up to 30 minutes (i.e. 1800 seconds), but the internals have much shorter flights on average. The internals have an average track life of around 22 minutes, compared to the other flight types which have an average track life of around 35 minutes.

### 3.3.3 Analysis of Horizontal Phase of Flight on Trajectory Accuracy

Horizontal phase of flight is calculated for each HCS track report and extracted for the trajectory accuracy measurements. This factor is categorized into two levels: straight or turn. The PHASE_D program that detects turns, described in Section 2.4.6.1, had its parameters set to protect against noise in the track data. As a result, rapid turns are detected but shallow turns may be missed. A turn is determined by a nine degree angle (or greater) generated by the two segments drawn from the previous position to the current position and the current position to the next position report.

The analysis that follows examines whether the mean of the trajectory prediction error at the two horizontal phases of flight are significantly different statistically at the four look ahead times of zero, 600, 1200, and 1800 seconds. This analysis will focus on these four look ahead times and two phases of flight against the signed lateral, longitudinal, vertical, and horizontal errors. Appendix A.1 contains a more complete set of look ahead times and also includes the descriptive statistics on the unsigned or absolute values of the errors. Figures 3.3-11 to 3.3-14 plot the means for each horizontal phase of flight as a function of look ahead time (LH), where STR denotes straight and TRN denotes turning.

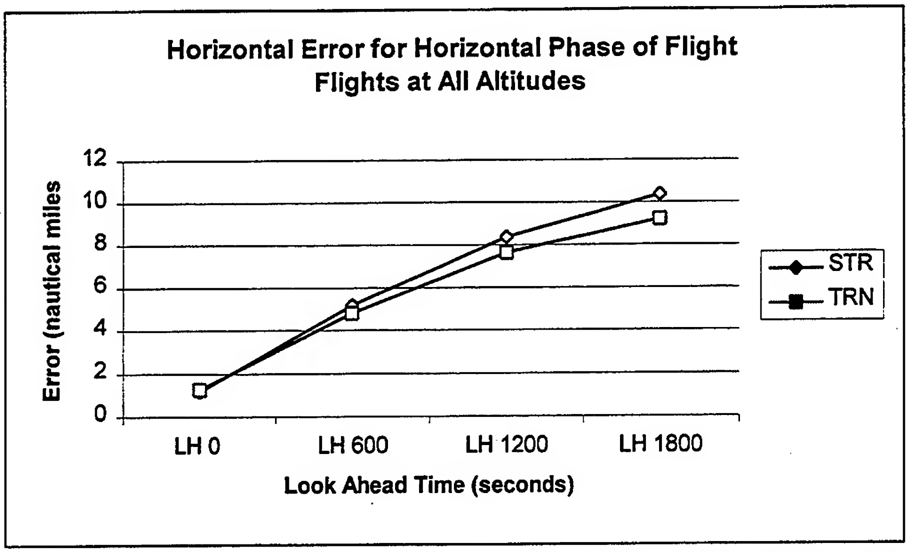


**Figure 3.3-11: Sample Means for Horizontal Error per Horizontal Phase of Flight and LH**

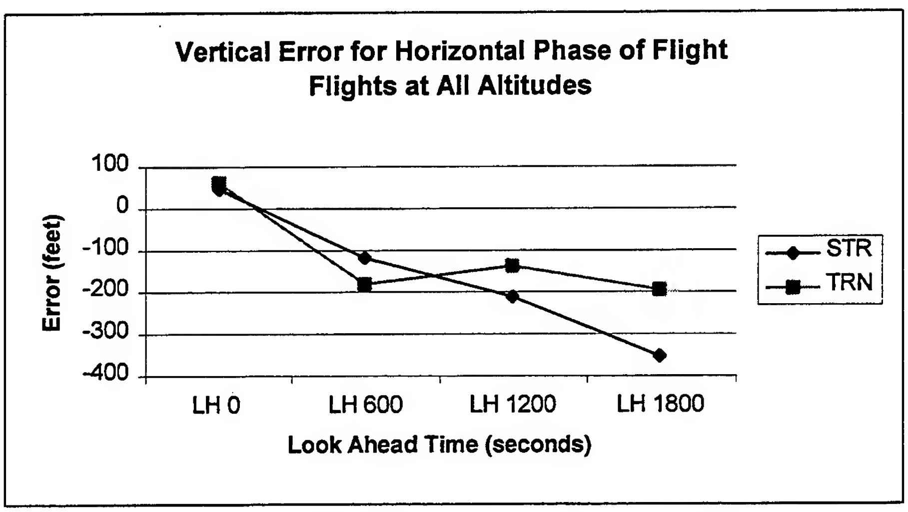


**Figure 3.3-12: Sample Means for Vertical Error per Horizontal Phase of Flight and LH**

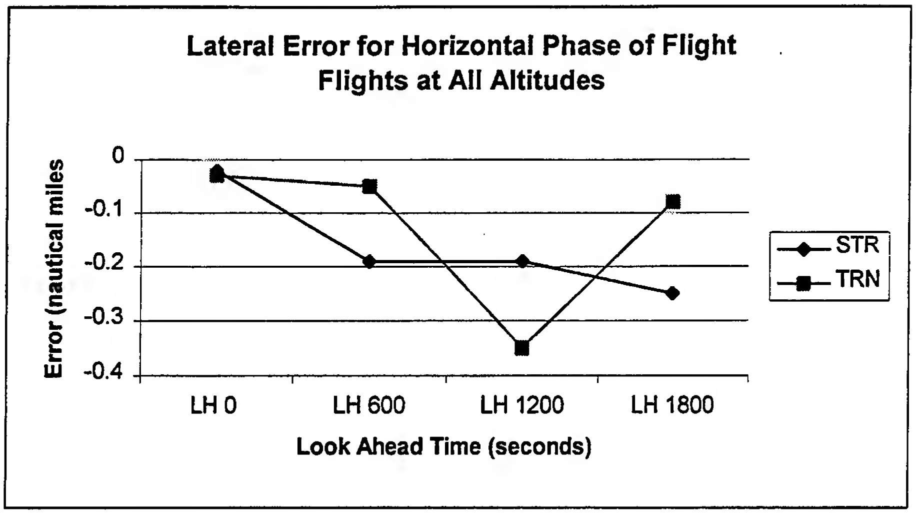


Figure 3.3-13: Sample Means for Lateral Error per Horizontal Phase of Flight and LH

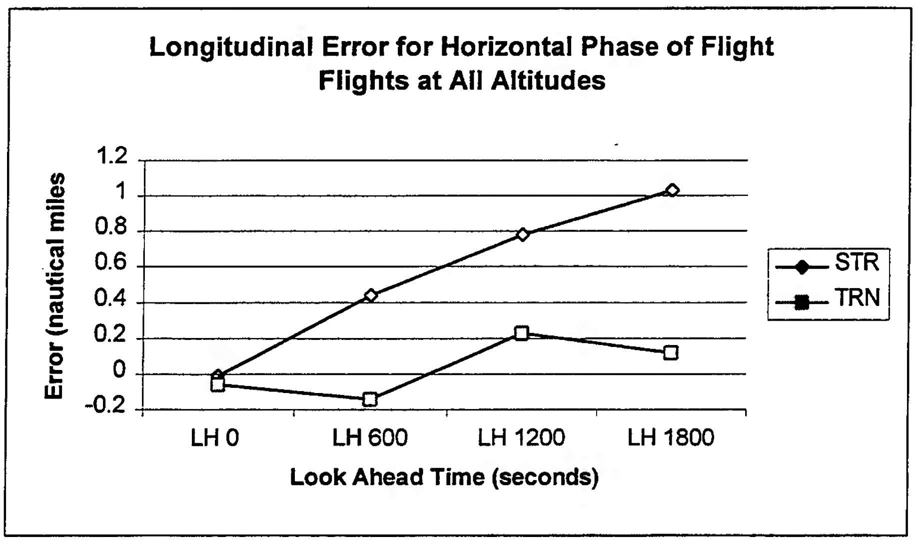


Figure 3.3-14: Sample Means for Longitudinal Error per Horizontal Phase of Flight and LH

### 3.3.3.1 Samples at all altitudes

The results for all altitudes are summarized in Table 3.3-10. The detailed histograms and statistical tables are located in Appendix A.1.

**Table 3.3-10: Statistical Results LH 0-30 minutes at All Altitudes**

| Error Type | Look ahead Time | Levene Test | Welch Test | Tukey-Kramer | Observations |
|---|---|---|---|---|---|
| Horizontal | 0 | Yes | Yes | Yes | Both mean and variance are significantly different. The means are around 600 feet different. |
| Lateral | 0 | Yes | No | No | Only variance is significantly different. |
| Long. | 0 | Yes | Yes | Yes | Both mean (around 300 feet) and variance are significantly different. |
| Vertical | 0 | Yes | No | No | Only variance is significantly different. |
| Horizontal | 600 | Yes | Yes | Yes | Both mean (around 900 feet) and variance are significantly different. |
| Lateral | 600 | Yes | No | No | Only variance is significantly different. |
| Long. | 600 | No | Yes | Yes | Means are different, around 0.6 nm. |
| Vertical | 600 | Yes | No | No | Only variance is significantly different. |
| Horizontal | 1200 | Yes | Yes | Yes | Both mean and variance are significantly different. The means differ around 1 nautical mile. |
| Lateral | 1200 | Yes | No | No | Only variance is significantly different. |
| Long. | 1200 | No | Yes | Yes | Means are significantly different. The means differ around 0.5 nautical mile. |
| Vertical | 1200 | No | No | No | Do not differ statistically. |
| Horizontal | 1800 | Yes | Yes | Yes | Both mean and variance are significantly different. The means differ around 1.2 nautical miles. |
| Lateral | 1800 | Yes | No | No | Only variance is significantly different. |
| Long. | 1800 | No | Yes | Yes | Means are significantly different. The means differ 0.9 nm. |
| Vertical | 1800 | No | Yes | Yes | Means are significantly different. The means differ around 160 feet. |

### 3.3.3.2 Samples at altitudes above 18,000 feet

The results are summarized in Table 3.3-11. The detailed histograms and statistical tables are located in Appendix A.1.

**Table 3.3-11: Statistical Results LH 0-30 minutes Above 18,000 feet**

| Error Type | Look ahead Time | Levene Test | Welch Test | Tukey-Kramer | Observations |
|---|---|---|---|---|---|
| Horizontal | 0 | Yes | No | No | Only variance is significantly different. |
| Lateral | 0 | No | No | No | Do not differ statistically. |
| Long. | 0 | No | No | No | Do not differ statistically. |
| Vertical | 0 | No | No | No | Do not differ statistically. |
| Horizontal | 600 | No | No | No | Do not differ statistically. |
| Lateral | 600 | No | No | No | Do not differ statistically. |
| Long. | 600 | No | Yes | Yes | Means differ around a 0.6 nm. |
| Vertical | 600 | No | No | No | Do not differ statistically. |
| Horizontal | 1200 | Yes | Yes | Yes | Both mean and variance are significantly different. The means differ around 1 nautical mile. |
| Lateral | 1200 | Yes | No | No | Only variance is significantly different. |
| Long. | 1200 | No | No | No | Do not differ statistically. |
| Vertical | 1200 | No | No | No | Do not differ statistically. |
| Horizontal | 1800 | Yes | Yes | Yes | Both mean and variance are significantly different. The means differ around 1.3 nautical miles. |
| Lateral | 1800 | Yes | No | No | Only variance is significantly different. |
| Long. | 1800 | No | Yes | Yes | Means are significantly different. The means differ around 1.3 nm. |
| Vertical | 1800 | No | Yes | Yes | Means are significantly different. The means differ around 230 feet. |

### 3.3.3.3 Discussion of the effect of Horizontal Phase of Flight

In general, the horizontal phase of flight, i.e. whether an aircraft is turning or on a straight path, had a significant effect on the horizontal prediction error and longitudinal error only for the all altitude samples. The magnitude of these differences between the means was rather small, approximately 0.1 to 1.2 nautical miles from zero to 1800 seconds look ahead time, respectively. The only other pattern of significant differences between means was the vertical error at 1800 seconds look ahead time, however the differences were very small, at around 150 feet. The results suggest that horizontal phase of flight has only a minor impact on the trajectory performance. There has also been some discussion on the need for analysis a small distance before and after the actual turn. The technique currently used for determining an aircraft is turning is not sufficiently robust in filtering out the noise of the HCS track reports nor can it examine the straight path around the turn. As a result, the statistical analysis of the effect of turns should be interpreted advisedly and the algorithm will be revisited in the future.

### 3.3.4 Analysis of Vertical Phase of Flight on Trajectory Accuracy

Similar to horizontal phase of flight, vertical phase of flight is calculated for each interpolated HCS track report and extracted for the trajectory accuracy measurements. Vertical phase of flight is categorized into three categories: level, ascending, or descending. The track points are only labeled as climbing or descending for reasonably large climbs and descents to protect against noise in the position data, but this also prevents detection of low rate climbs and descents (i.e. smaller than 900 feet per minute). A climb or descent is determined by calculating the difference in altitude between the current interpolated track position and the next track position. If the absolute difference is less than 150 feet, the current position of the aircraft is considered in level flight, otherwise the aircraft is in a climb or descent depending on the direction up or down. Since the track positions are interpolated at 10 second intervals, the required gradient for the climbing or descending aircraft is greater than or equal to 15 feet per second or 900 feet per minute. The phase of flight algorithm is described in detail in Section 2.4.6.

The analysis that follows examines whether the mean of the trajectory prediction error at the three vertical phases of flight are significantly different statistically at the four look ahead times of zero, 600, 1200, and 1800 seconds. This analysis focuses on these four look ahead times and three phases of flight against the signed lateral, longitudinal, vertical, and horizontal errors. Appendix A.1 contains a more complete set of look ahead times and also includes the descriptive statistics on the unsigned or absolute values of the errors. Figures 3.3-15 to 3.3-18 plot the means for each vertical phase of flight as a function of look ahead time (LH), where LEV denotes level flight, ASC denotes ascending and DES denotes descending.

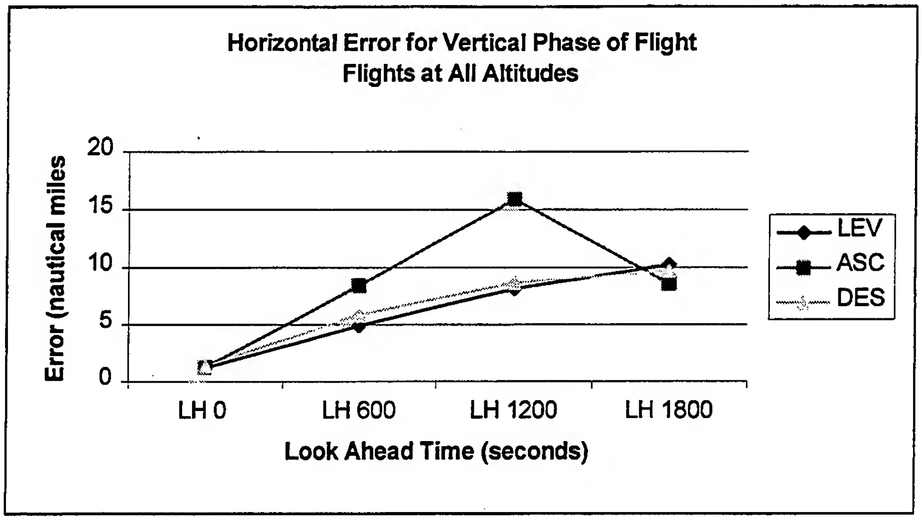


**Figure 3.3-15: Sample Means for Horizontal Error per Vertical Phase of Flight and LH**

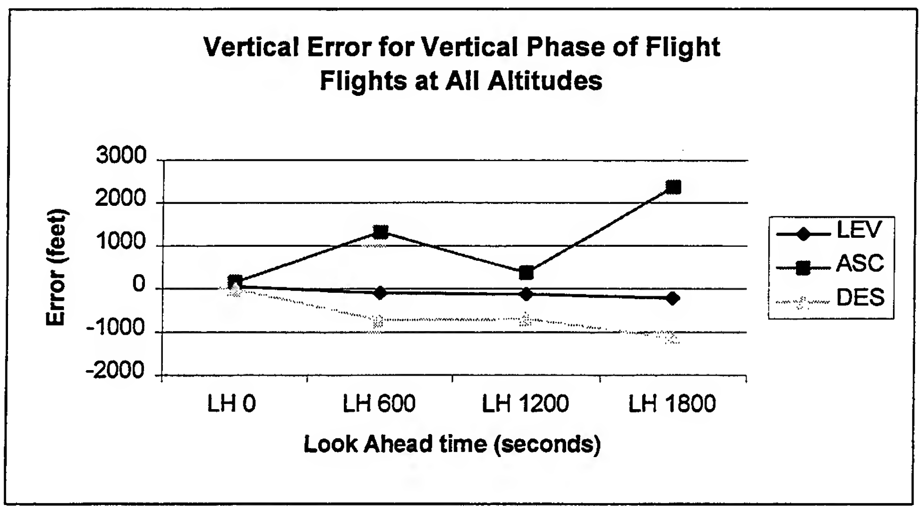


**Figure 3.3-16: Sample Means for Vertical Error per Vertical Phase of Flight and LH**

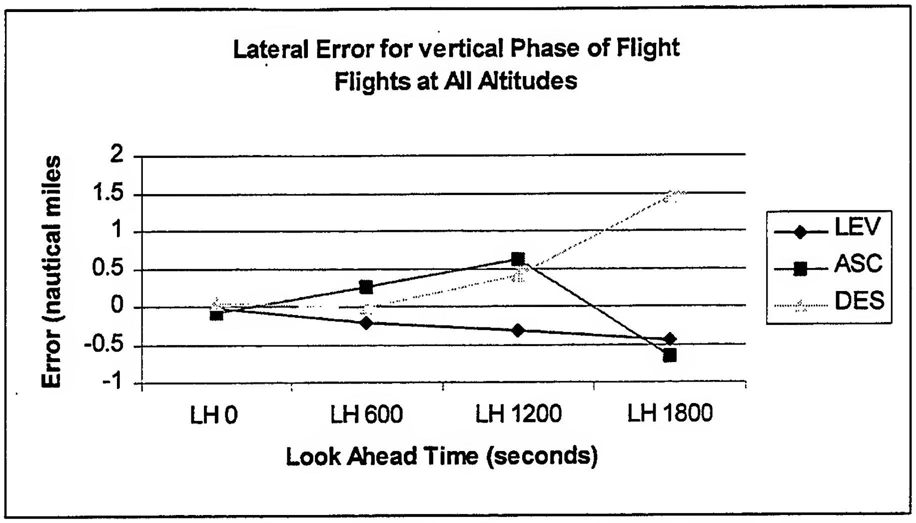


**Figure 3.3-17: Sample Means for Lateral Error per Vertical Phase of Flight and LH**

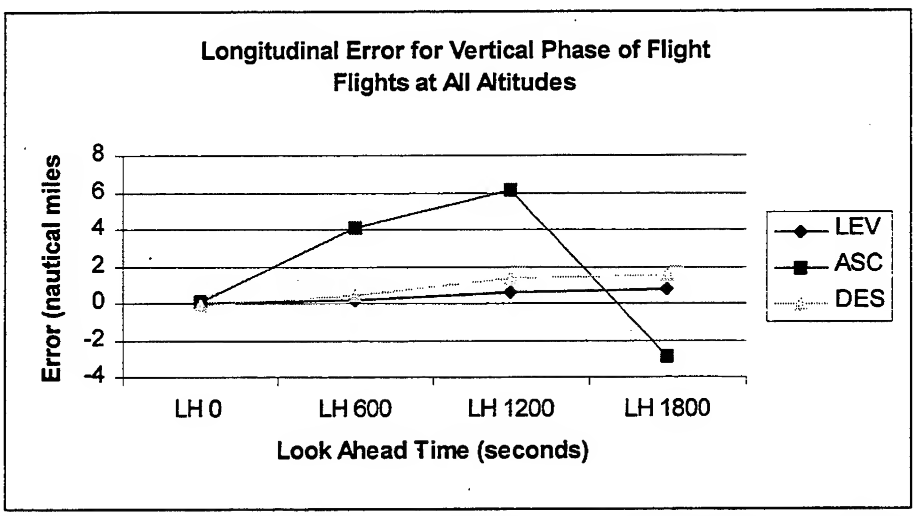


**Figure 3.3-18: Sample Means for Longitudinal Error per Vertical Phase of Flight and LH**

### 3.3.4.1 Samples at all altitudes

The results are summarized in Table 3.3-12. The detailed histograms and statistical tables are located in Appendix A.1.

**Table 3.3-12: Statistical Results LH 0-30 minutes at All Altitudes**

| Error Type | Look ahead Time | Levene Test | Welch Test | Tukey-Kramer | Observations |
|---|---|---|---|---|---|
| Horizontal | 0 | Yes | Yes | Yes-2of3 | Only level versus ascent not different, but others around a maximum of 1000 feet different. |
| Lateral | 0 | Yes | Yes | Yes-all | Both mean and variance are significantly different. |
| Long. | 0 | Yes | Yes | Yes-all | Both mean and variance are significantly different. |
| Vertical | 0 | Yes | Yes | Yes-all | Both mean (around 160 feet) and variance are significantly different. |
| Horizontal | 600 | Yes | Yes | Yes-all | Both mean (by as much as 3.6 nm) and variance are significantly different. |
| Lateral | 600 | Yes | Yes | Yes-1of3 | Only ascent versus level differ. |
| Long. | 600 | Yes | Yes | Yes-all | Both mean (by as much as 3.9 nm) and variance are significantly different. |
| Vertical | 600 | Yes | Yes | Yes-all | Both mean (by as much as 2000 feet) and variance are significantly different. |
| Horizontal | 1200 | Yes | Yes | Yes-2of3 | Only level versus descent not different, and others differ by as much as 7.75 nm. |
| Lateral | 1200 | No | Yes | Yes-1of3 | Only means descent versus level are significantly different. |
| Long. | 1200 | Yes | Yes | Yes-all | Mean (by as much as 5.5 nm) and variance are significantly different. |
| Vertical | 1200 | Yes | Yes | Yes-2of3 | Both mean and variance are significantly different, except level versus ascent. The means differ by as much as 1100 feet. |
| Horizontal | 1800 | Yes | No | No | Only variance is significantly different. Inconclusive on ascents, only 11 samples. |
| Lateral | 1800 | No | Yes | Yes1of3 | Only mean of descent versus level different. Inconclusive on ascents, only 11 samples. |
| Long. | 1800 | No | No | No | Do not differ statistically. Inconclusive on ascents, only 11 samples. |
| Vertical | 1800 | Yes | Yes | Yes | Means are significantly different. The means differ by as much as 3500 feet. Inconclusive on ascents, only 11 samples. |

### 3.3.4.2 Samples at altitudes above 18,000 feet

The results are summarized in Table 3.3-13. The detailed histograms and statistical tables are located in Appendix A.1.

**Table 3.3-13: Statistical Results LH 0-30 minutes Above 18,000 feet**

| Error Type | Look ahead Time | Levene Test | Welch Test | Tukey-Kramer | Observations |
|---|---|---|---|---|---|
| Horizontal | 0 | Yes | Yes | Yes-2of3 | Only level versus ascent not different, but others around a maximum of 600 feet different. |
| Lateral | 0 | Yes | Yes | No | Tukey-Kramer shows no difference in means but has less power than Welch Test which had a p-value of 0.48. |
| Long. | 0 | Yes | Yes | Yes-2of3 | Only descent versus level means are not significantly different |
| Vertical | 0 | Yes | Yes | Yes-all | Both mean (around 220 feet) and variance are significantly different. |
| Horizontal | 600 | Yes | Yes | Yes-all | Both mean (by as much as 3.5 nm) and variance are significantly different. |
| Lateral | 600 | Yes | No | No | Only variance is significantly different. |
| Long. | 600 | Yes | Yes | Yes-2of6 | Only descent versus level means are not significantly different. |
| Vertical | 600 | Yes | Yes | Yes-all | Both mean (by as much as 1600 feet) and variance are significantly different. |
| Horizontal | 1200 | Yes | Yes | Yes-2of3 | Only level versus descent not different, and others differ by as much as 7 nm. |
| Lateral | 1200 | No | Yes | Yes-1of3 | Only descent versus level are significantly different. |
| Long. | 1200 | Yes | Yes | Yes-2of3 | Only descent versus level not different, and others differ by as much as 8.26 nm. |
| Vertical | 1200 | Yes | Yes | Yes-2of3 | Except level versus ascent means, both mean and variance are different. The means differ by as much as 970 feet. |
| Horizontal | 1800 | Yes | Yes | Yes-1of3 | Only descent versus level are different, around 2 nautical miles. Inconclusive on ascents, only 10 samples. |
| Lateral | 1800 | Yes | Yes | Yes-1of3 | Only descent versus level means are different, around 1.75 nautical miles. Inconclusive on ascents, only 10 samples. |
| Long. | 1800 | Yes | No | No | Only variance is significantly different. Inconclusive on ascents, only 10 samples. |
| Vertical | 1800 | Yes | Yes | Yes-all | Means differ by as much as 3300 feet. Inconclusive on ascents, only 10 samples. |

### 3.3.4.3 Discussion of the effect of Vertical Phase of Flight

In general for both horizontal and vertical dimensions, level flight has the smallest mean and variance error, while ascending flight has the largest as look ahead time increases. At a look ahead time of zero, both ascent and level are not significantly different, but at look ahead time of 1800 not much can be drawn on ascending flight from these samples because around 10 samples were available. In practically all cases, the variance was significantly different. Also as the look ahead time increases, the standard deviation increases and the difference in standard deviation between levels increases. For example, for vertical error at look ahead time zero seconds, the standard deviation ranges from around 620 feet to 940 feet, but at look ahead time 1200 seconds the standard deviation ranges from around 1860 feet to 3200 feet.

# 4. CTAS Study Results and Observations

The results and observations presented in this section are based on the analysis of seven hours of data recorded at the Fort Worth ARTCC (ZFW). Specific information describing the scenario is presented in Section 4.1. Section 4.2 provides detailed information about one aircraft flight in the study in order to demonstrate the study's methodology, and Section 4.3 presents the results of the application of the trajectory accuracy metrics to CTAS.

## 4.1 Scenario Description

Figure 4.1-1 provides a data flow diagram logically describing the data files and processes used to obtain the flight plan, track, and trajectory data used for the CTAS analysis. For this study, data was collected from the CTAS installation at ZFW. A recording was made of the HCS flight plans, flight plan amendments, and track messages sent to CTAS over a seven hour period on January 5, 1999. The weather data for the same time period was also recorded.

NASA Ames Research Center provided the ZFW data to ACT-250 in file called *ZFW_010599.cm_sim*. This file was used as input to a playback run through a developmental version of CTAS also provided by NASA Ames. This version of CTAS, called *daisy_view*, was modified by ACT-250 to provide trajectories in its output file. These trajectories consist of 31 points, each point separated in time by 65 seconds. As a result, all of the CTAS trajectories were 1950 seconds or less in length. This output file is identified as *baseline.cm_sim* in Figure 4.1-1. The CTAS Parser Program (CPP) used the *baseline.cm_sim* file to create three files: the *fp.dat* file, containing flight plan data; the *track.dat* file, containing track data; and the *traj_file.dat* file, containing trajectory data. The *fp.dat* file was then concatenated with the *track.dat* file to create an ASCII file called *sn010599.dat,* containing CTAS field data, that has the same format as the *sn022798.dat* described for URET field data in Section 3.1. The *sn010599.dat* file was then used as input to the Flight Plan and Track Data Processing described in Section 2.4.1. The *traj_file.dat* file has the same format as its URET counter part described in Section 3.1 and was used as input to the Trajectory Data Processing described in Section 2.5. The formats of the *sn010599.dat* and *traj_file.dat* files are described in WJHTC/ACT-250, 1998.

Tables 4.1-1 and 4.1-2 summarize the characteristics of the airspace and the aircraft flights through the airspace, respectively, for the subject scenario.

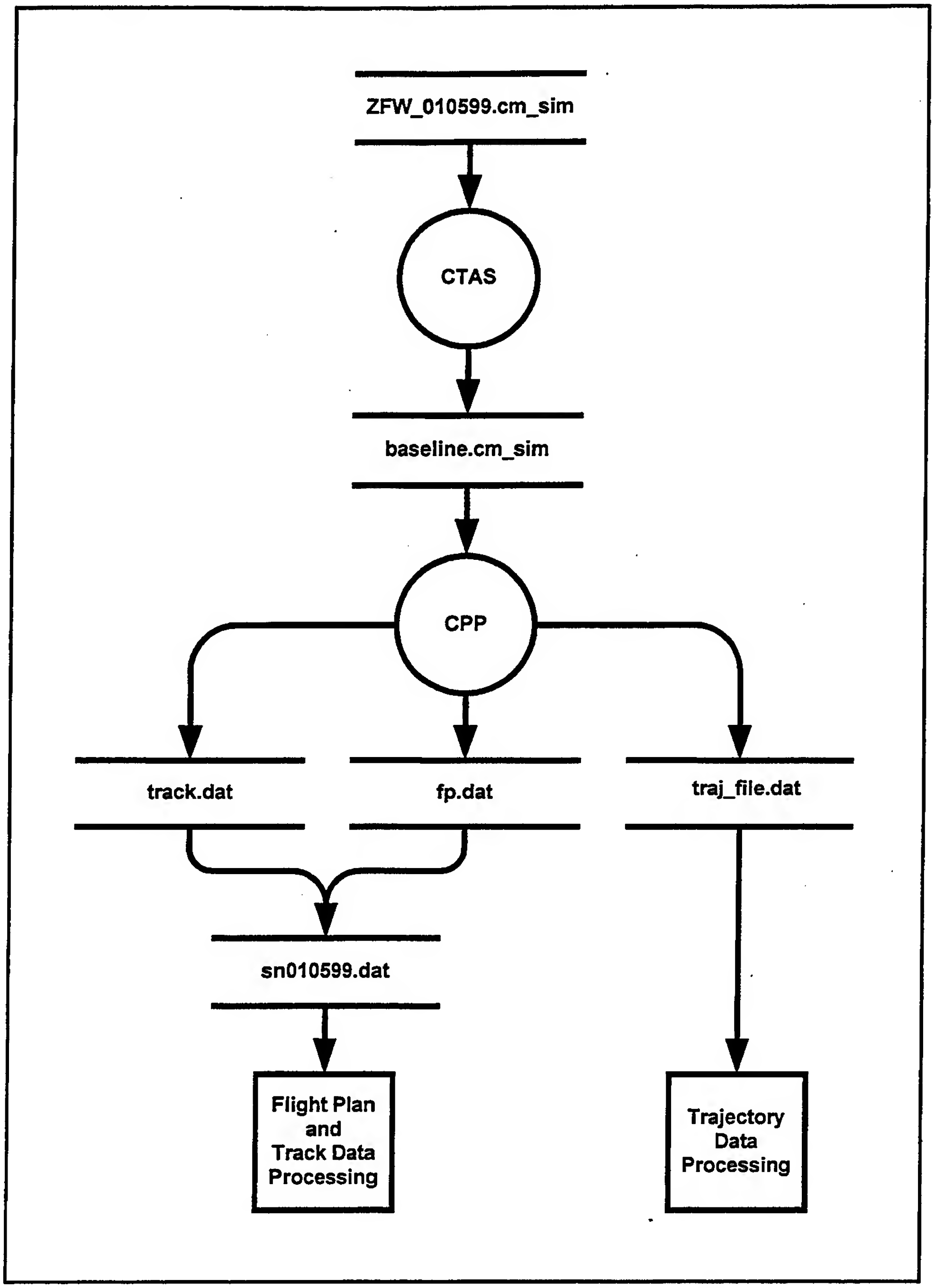


**Figure 4.1-1: CTAS Data Sources**

### 4.1.1 Airspace Definition

Table 4.1-1 summarizes the spatial and time boundaries of the ZFW data sample used.

**Table 4.1-1: CTAS Scenario - Airspace**

| | |
|---|---|
| Airspace | Fort Worth (ZFW) |
| Altitude | 0 to 60,000 feet |
| Horizontal boundaries | Defined by the high altitude sectors |
| Date | January 5, 1999 |
| Start time | 18:39:35 UTC (12:40 p.m. local time) |
| End time | 01:43:26 UTC (7:43 p.m. local time) |
| Duration | 07:03:51 or 25,431 seconds |

### 4.1.2 Aircraft Counts

Table 4.1-2 gives the counts of aircraft flights in the sample of air traffic analyzed.

**Table 4.1-2: CTAS Scenario – Aircraft Counts**

| | |
|---|---|
| Total number in sample (IFR) | 2592 |
| Number excluded | 297 (11.5 %) |
| Number processed | 2295 (88.5 % of total) |
| Number of airliners | 1699 |
| Number of General Aviation aircraft | 596 |
| Number of jet types in the top 20 aircraft | 15 |
| Number of turboprop types in the top 20 aircraft | 4 |
| Number of piston types in the top 20 aircraft | 1 |
| Average length of track supplied by HCS | 37.6 minutes, 2253 seconds, or 189 position reports |
| Number of overflights | 255 (11.1 %) |
| Number of departures | 506 (22.1 %) |
| Number of arrivals | 586 (25.6 %) |
| Number of internal flights | 945 (41.2 %) |

### 4.1.3 Excluded Flights

In measuring the accuracy of track predictions, the true positions of the aircraft are assumed to be the positions reported by the HCS. For some aircraft, it is clear that the HCS reported positions are not correct. Track processing algorithms (in the RDTRACKS program) were used to correct the position data where possible, as described in Section 2.4.3. When it was not possible to correct the data, the individual track reports and in some cases entire flights were deleted from the scenario being examined. Statistics were collected on an aircraft flight only if both a track and a set of predicted trajectories were available. For this analysis of CTAS, there were three categories of excluded aircraft, totaling 297 flights that were deleted from the original set of 2592 IFR flights (a reduction of 11.5 %).

#### 4.1.3.1 Military Flights

Since it is often not possible from flight plan data to accurately predict the flight paths of military flights, which usually are doing either gunnery practice or aerial re-fueling maneuvers, military flights were excluded from the analysis. This was done by selecting out all of the flights which had a call sign containing more than three leading alphabetic characters (e.g., ANVIL, CODER, RACER, SABER, STEEL). Although this is not an exact definition of military aircraft, it was considered to be sufficient for this study. 99 military flights were excluded.

#### 4.1.3.2 Non-initialized Flights

As discussed in Section 2.4, sometimes the HCS processing algorithms are unable to establish a consistent track for the aircraft. Ten of these flights were excluded.

#### 4.1.3.3 Uncertain Position Flights

The processing of the HCS track data requires correcting some of the track reports which are clearly in error. For example, as discussed in Section 2.4.3, sometimes the same XY coordinates are repeated even though the aircraft has moved between the radar reports. In some cases the corrected track reports are substantially different from the original aircraft positions reported by the HCS. This situation implies that we, the experimenters, do not know the true position of the aircraft. Flights having a corrected position report substantially different from the original position report were deleted (188 of these flights were excluded).

### 4.1.4 Truncated Flights

Often in the HCS track reports several tracks reports are missing or have bad data. If a gap in the track data is short, the missing track reports can be replaced by interpolation. If the gap is large, the position of the aircraft during the gap is unknown. When a large gap in the track data occurs, the track after the gap is discarded. Of the 441,557 radar track position reports, 14,333 or 3.2 % of the radar track position reports were discarded by truncating the tracks after missing or bad data.

Measurements of trajectory prediction errors were made on aircraft either already in the ZFW airspace or approaching the ZFW airspace and about to be in the ZFW airspace. Measurements were not made on aircraft after they left the ZFW airspace. That is, no measurements were made on the portions of the tracks outside ZFW when the aircraft were flying away from the ZFW airspace. 12.6 % of the interpolated track reports were not used for this reason.

### 4.1.5 Aircraft Mix

The majority of the aircraft in the study are commercial airliners. The top 10 aircraft types account for 1310 of the 2295 flights, or 57.1 % of the total; the top 20 aircraft account for 1632 of the 2295 flights, or 71.1 % of the total. A histogram depicting the frequency of occurrence of the top 20 aircraft is provided in Figure 4.1-2. The aircraft are identified by their FAA type designators. Of the top 20 aircraft, 15 are jets, four are turboprops, and one is a piston-powered aircraft. Table 4.1-3 lists the aircraft manufacturers and model names of the top 10 aircraft. All of the top 10 aircraft are jets except for the Saab & Fairchild 340 which is a turboprop.

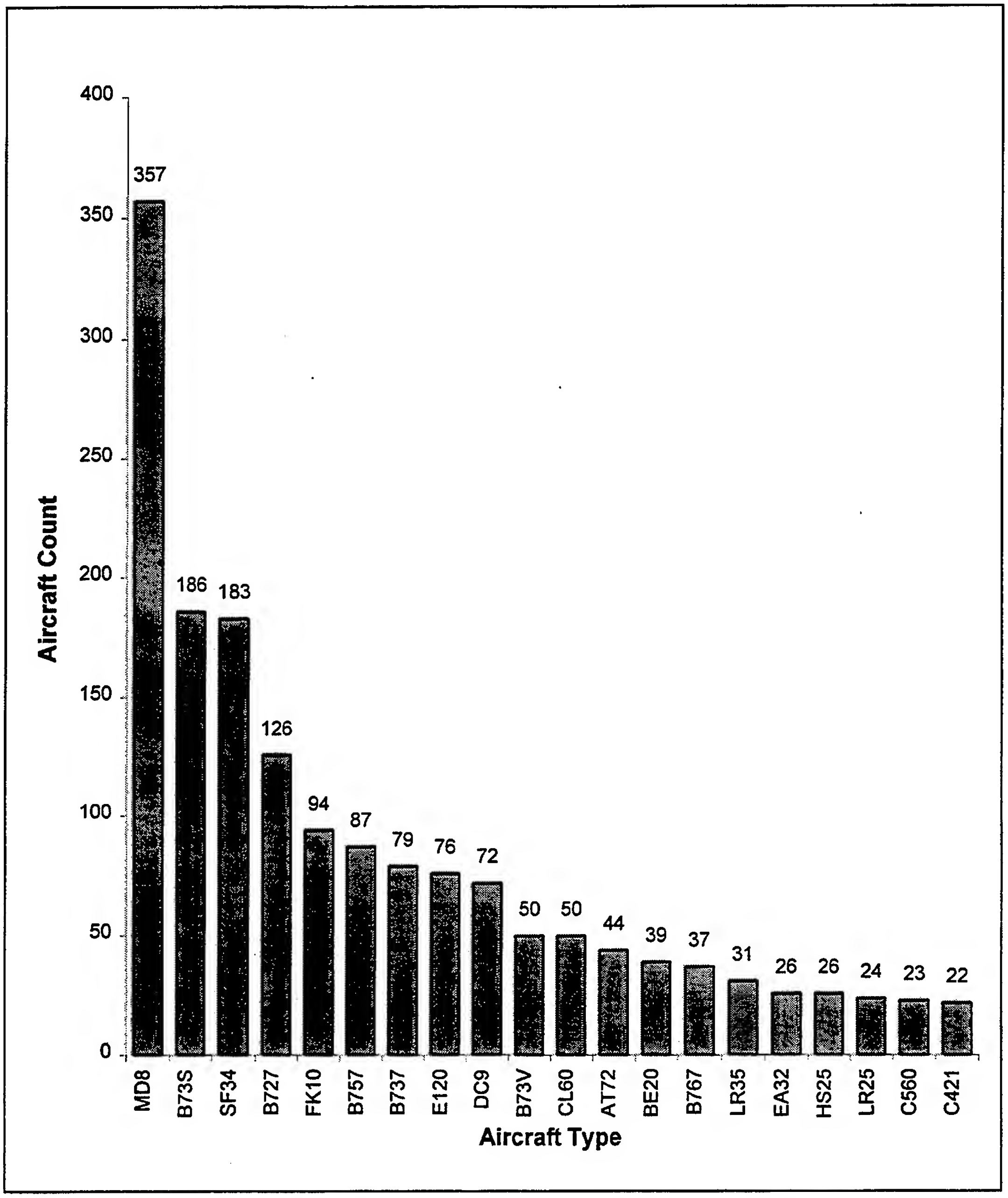


**Figure 4.1-2: Top 20 Aircraft Frequency Histogram - ZFW Data**

**Table 4.1-3: CTAS Scenario Aircraft**

| RANK | FAA TYPE IDENTIFIER | MANUFACTURER / MODEL | NUMBER OF FLIGHTS | PERCENTAGE OF FLIGHTS |
|---|---|---|---|---|
| 1 | MD8 | McDonnell-Douglas MD-80 | 357 | 15.56 % |
| 2 | B73S | Boeing 737 – 300/500 | 186 | 8.10 % |
| 3 | SF34 | Saab & Fairchild 340 | 183 | 7.97 % |
| 4 | B727 | Boeing 727 | 126 | 5.49 % |
| 5 | FK10 | Fokker 100 | 94 | 4.10 % |
| 6 | B757 | Boeing 757 | 87 | 3.79 % |
| 7 | B737 | Boeing 737 – 200 | 79 | 3.44 % |
| 8 | E120 | Embraer EMB 120 | 76 | 3.31 % |
| 9 | DC9 | McDonnell-Douglas DC9 | 72 | 3.14 % |
| 10 | B73V | Boeing 737 | 50 | 2.18 % |

## 4.2 Observations

This section presents observations made during analysis of the data, which provide detailed information about a specific aircraft flight in the CTAS study. These observations are included before the results so that the reader can better understand the methodology, and therefore better understand the statistics and data presented in Section 4.3. While each observation details a typical flight, the errors are not necessarily representative of common occurrences. Appendix C provides additional anomalous flights, which were selected to verify the methodology and to examine trajectory accuracy errors with CTAS.

### 4.2.1 CTAS1

This flight is a DC9 flying from Dallas/Fort Worth International Airport (DFW) to the Minneapolis-St. Paul International Airport (MSP). It departed via TEX6 through the ZEMMA intersection and proceeded to the Tulsa VORTAC (TUL). From TUL it took J25 to MSP, passing through Kansas City, Des Moines, and Mason City. The cruising altitude was 29,000 feet. The first part of the flight's filed route from DFW to ZEMMA, to TUL and past is shown in Figure 4.2-1.

#### 4.2.1.1 Track Data

The HCS radar track started at 9,500 feet west of DFW and headed initially toward the ZEMMA intersection. About halfway there, the aircraft switched its heading toward the TUL waypoint. The horizontal track is shown in Figure 4.2-1 and in Figure 4.2-3 where the West-East scale (X axis) has been expanded by a factor of 4 to better show the location of the predicted trajectories relative to the track.

During the climb out from DFW to 29,000 feet the aircraft leveled off at 24,000 feet for three minutes before continuing the climb. The aircraft exits the ZFW airspace at level cruise at 29,000 feet. The altitude profile is shown in Figure 4.2-4.

As described in detail in Section 2.4.3, RDTRACKS processed the HCS track which included 195 position reports. First, the time intervals between track reports were examined. There were 35 of the 194 time differences between successive position reports that were equal to 11 seconds. These were changed to 12 seconds. There were 37 reports with a 13 second time difference that were changed to 12 seconds. There was one 10 second time difference that was changed to 12

seconds. There was one 14 second time difference that was changed to 12 seconds. Finally, there were two reports with a 23 second time difference that were changed to 24 seconds.

The first two reports were discarded because of inconsistent altitude values. Another track report defined as stationary had XYZ values of the immediately preceding report. The values of XYZ for this report are replaced with interpolated values. Two reports occur 24 seconds after the immediately preceding report rather than 12 seconds later. An additional interpolated track report is inserted to fill the gap in each case.

#### 4.2.1.2 Trajectory Data

Figure 4.2-2 presents the track time line (labeled "Track") and the time line for 23 of the 168 trajectories recovered for this aircraft. Each of the trajectories is labeled with the trajectory's build time. The sample points for calculating the trajectory accuracy metrics are shown by arrows drawn from the track time line to the latest trajectory available at that sample time. The first sample starts 40 seconds after the time of the initial interpolated track point, which in this example was at 84480 seconds. 19 of the 23 trajectories shown were sampled. The aircraft departed the ZFW Center airspace at 86210 and therefore the data from the last 4 trajectories were not used.

Plots of these trajectories are shown in Figure's 4.2-1, 4.2-3, and 4.2-4. The first 6 sampled trajectories predicted the aircraft would fly to the ZEMMA intersection. After the flight flew by the ZEMMA intersection, the trajectories (Trajectory 7 and later) predicted a flight to TUL. By the eighth sampled trajectory the predicted speed and altitude matched the track.

The first five trajectories predicted the aircraft to climb to 29,000 feet; Trajectories 6 and 7 climbed the aircraft to 23,400 feet and 24,000 feet respectively. Later trajectories climbed the aircraft to 29,000 feet except for Trajectory 10 which climbed the aircraft to 28,500 feet.

#### 4.2.1.3 Metrics

Table 4.2-1 shows the trajectory metrics calculated for this aircraft. The longitudinal and lateral errors are in nautical miles; the vertical errors are in feet. As discussed in Section 2.5.1, a sample is taken 40 seconds after the start of track and then repeated each two minutes until either the track ends, the trajectory ends, or the track leaves the center. At each sample time the distance between the track and trajectory was calculated at the current time and at look ahead times of 300 seconds or five minute increments into the future; resulting in look ahead times of 0, 300, 600, 900, 1200, 1500, and 1800 seconds.

The data shows that the lateral and longitudinal errors, although very small at low look ahead times because CTAS builds a new trajectory with each new track point, increased at the higher look ahead times early in the flight. This is because the aircraft flew inside the ZEMMA waypoint and flew direct to TUL.

It can be seen in Figure 4.2-4 that the initial estimates of climb rate were too high. By Trajectory 5 the estimate matched the actual track climbing rate. The interim altitude of 24,000 feet confuses the prediction of the final cruising altitude. Both the errors in estimating the climb rate and the errors in predicting the cruising altitude produce the large vertical prediction errors listed in Table 4.2-1.

Table 4.2-1 also shows that metrics were not computed after time 86160 because the aircraft departed the ZFW airspace at 86210.

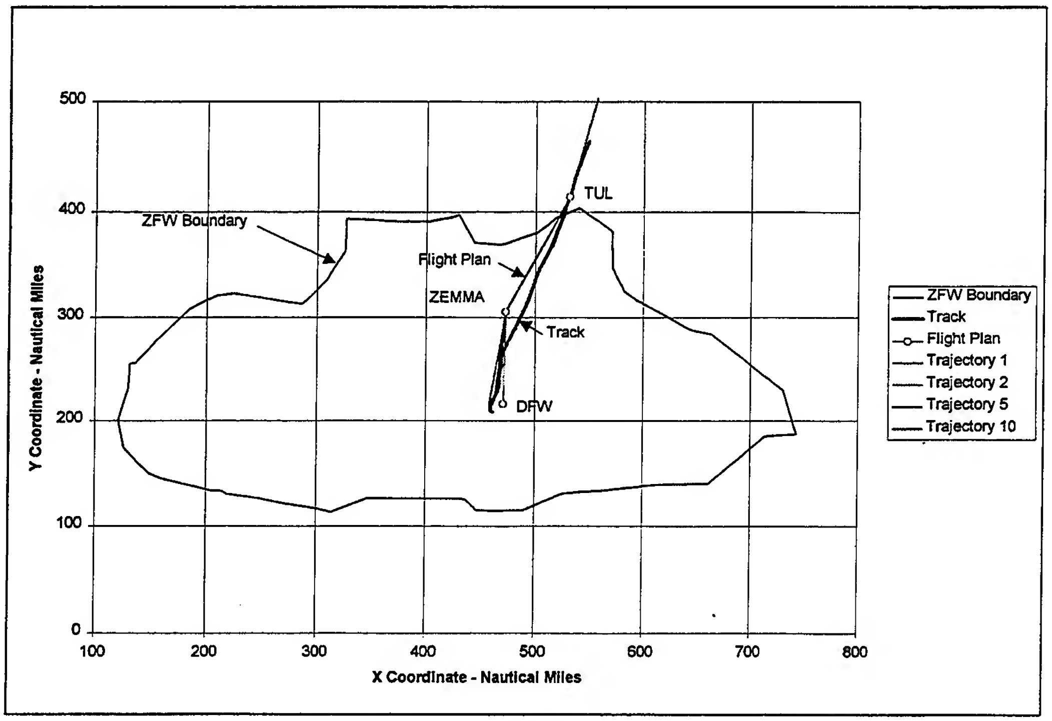


**Figure 4.2-1: Aircraft Track and Route**

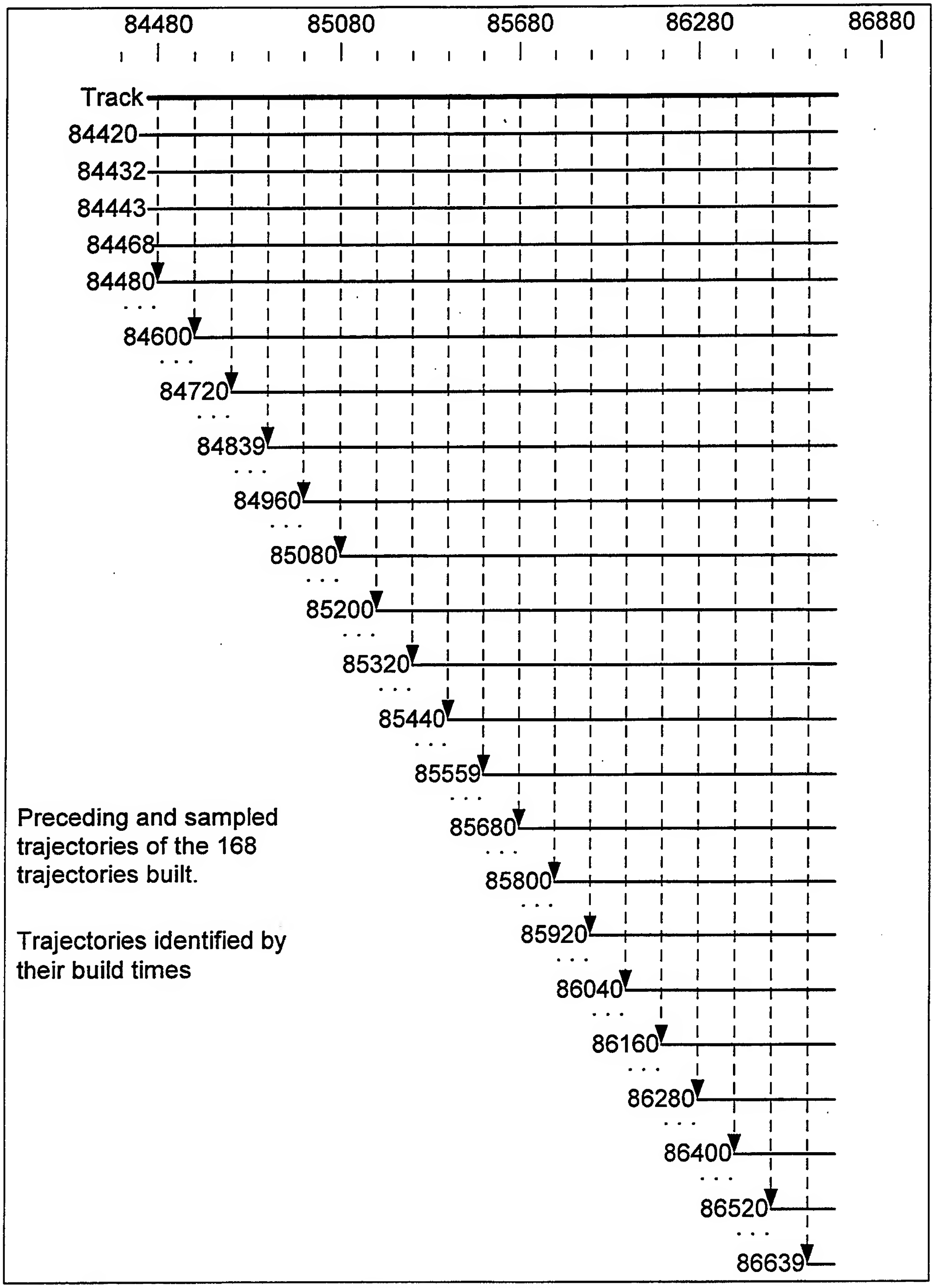


**Figure 4.2-2: Sampled Trajectories**

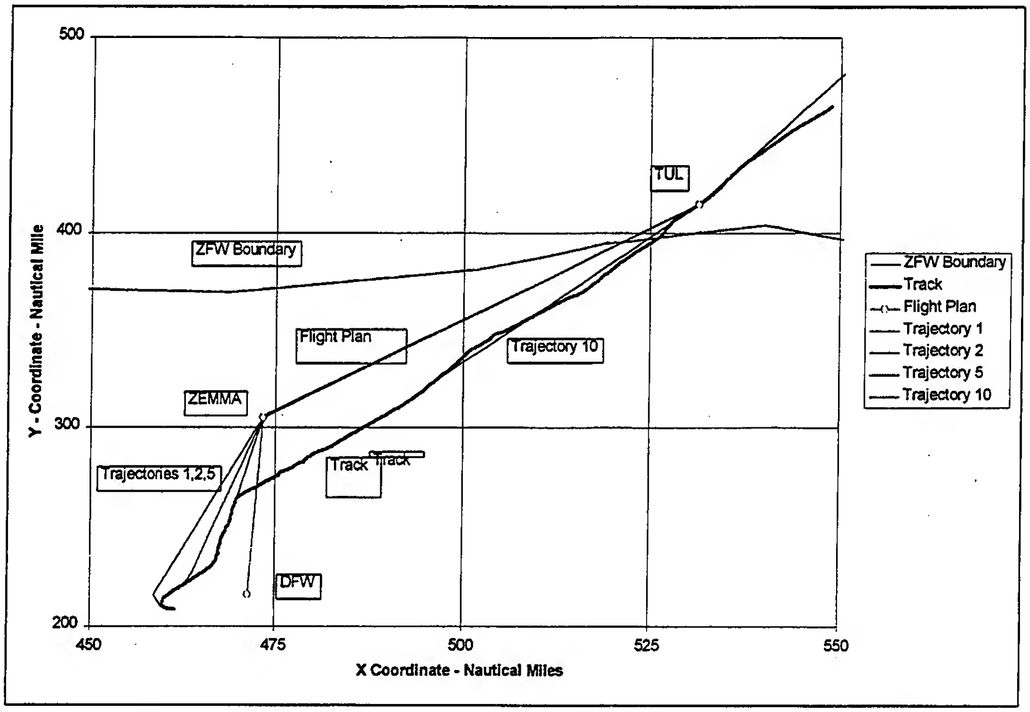


**Figure 4.2-3: XY Track and Trajectories**

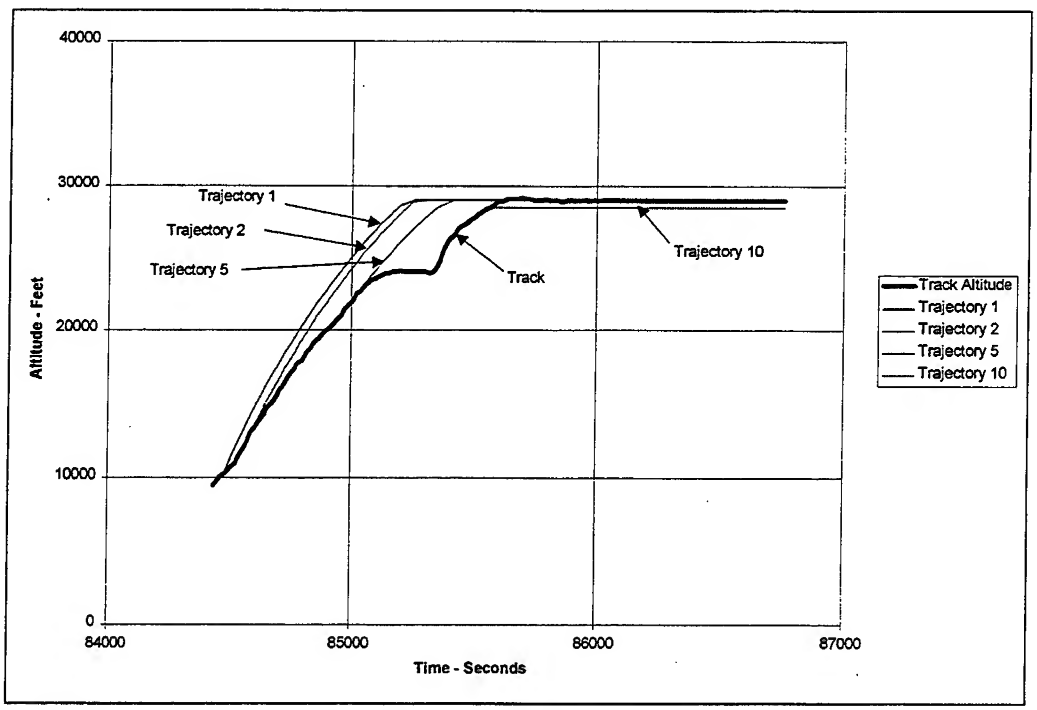


**Figure 4.2-4: Altitude and Trajectory**

Table 4.2-1: Trajectory Metrics (1 of 2)[9]

| Sample Time | Traj No | Traj Build Time | Look Ahead Time | Long Error | Lat Error | Vert Error |
|---|---|---|---|---|---|---|
| 84480 | 1 | 84480 | 0 | 0.00 | 0.01 | 0.00 |
| | | | 300 | 2.70 | 4.90 | -2028.92 |
| | | | 600 | 3.84 | 4.77 | -3188.23 |
| | | | 900 | 7.82 | 14.83 | -3314.00 |
| | | | 1200 | 14.03 | 9.07 | 86.00 |
| | | | 1500 | 18.40 | 7.07 | -14.00 |
| 84600 | 2 | 84600 | 0 | 0.00 | 0.00 | 0.00 |
| | | | 300 | 2.45 | 1.93 | -1852.62 |
| | | | 600 | 4.67 | 8.12 | -3975.92 |
| | | | 900 | 12.21 | 14.03 | -1212.00 |
| | | | 1200 | 15.64 | 7.50 | -12.00 |
| | | | 1500 | 19.43 | 4.63 | -12.00 |
| 84720 | 3 | 84720 | 0 | 0.00 | 0.00 | 100.00 |
| | | | 300 | 0.48 | 0.07 | -1088.23 |
| | | | 600 | 0.59 | 12.14 | -4848.54 |
| | | | 900 | 5.07 | 10.70 | -7.00 |
| | | | 1200 | 6.16 | 7.08 | -7.00 |
| 84840 | 4 | 84839 | 0 | -0.10 | 0.00 | -25.74 |
| | | | 300 | 1.14 | 4.61 | -1788.82 |
| | | | 600 | 8.53 | 13.93 | -1912.00 |
| | | | 900 | 8.30 | 8.11 | -12.00 |
| | | | 1200 | 11.19 | 5.76 | -12.00 |
| 84960 | 5 | 84960 | 0 | 0.00 | 0.00 | 0.00 |
| | | | 300 | 0.77 | 9.81 | -3105.08 |
| | | | 600 | 6.13 | 11.99 | -502.00 |
| | | | 900 | 6.25 | 7.35 | -102.00 |
| | | | 1200 | 7.13 | 3.77 | -2.00 |
| 85080 | 6 | 85080 | 0 | 0.00 | -0.01 | 0.00 |
| | | | 300 | 4.61 | 14.54 | 2300.00 |
| | | | 600 | 16.67 | 9.41 | 5700.00 |
| | | | 900 | 23.88 | 7.24 | 5600.00 |

[9] In this chart, longitudinal and lateral error are reported in hundredths of nautical miles, and the vertical error is reported in hundredths of feet. The precision of the input HCS altitude data is reported to the nearest 100 feet, the apparent difference is simply an artifact of the track report processing.

Table 4.2-1: Trajectory Metrics (2 of 2)

| Sample Time | Traj No | Traj Build Time | Look Ahead Time | Long Error | Lat Error | Vert Error |
|---|---|---|---|---|---|---|
| 85200 | 7 | 85200 | 0 | 0.00 | 0.00 | 100.00 |
| | | | 300 | 2.49 | 0.96 | 3800.00 |
| | | | 600 | 5.64 | -0.45 | 5000.00 |
| | | | 900 | 10.13 | 1.09 | 5000.00 |
| 85320 | 8 | 85320 | 0 | 0.00 | -0.01 | -100.00 |
| | | | 300 | -1.84 | 0.19 | 408.31 |
| | | | 600 | -1.96 | 0.95 | -10.00 |
| 85440 | 9 | 85440 | 0 | 0.00 | -0.01 | 100.00 |
| | | | 300 | -1.13 | -1.42 | -11.00 |
| | | | 600 | 0.64 | 1.07 | -11.00 |
| 85560 | 10 | 85559 | 0 | -0.11 | 0.00 | 0.00 |
| | | | 300 | 2.32 | 0.00 | 400.00 |
| | | | 600 | 5.44 | 0.98 | 500.00 |
| 85680 | 11 | 85680 | 0 | 0.00 | 0.00 | 100.00 |
| | | | 300 | 1.52 | 2.29 | 0.00 |
| 85800 | 12 | 85800 | 0 | 0.00 | 0.00 | 0.00 |
| | | | 300 | 0.80 | 1.19 | 0.00 |
| 85920 | 13 | 85920 | 0 | 0.00 | 0.00 | 0.00 |
| 86040 | 14 | 86040 | 0 | 0.00 | 0.00 | 0.00 |
| 86160 | 15 | 86160 | 0 | 0.00 | 0.00 | 0.00 |

## 4.3 Results

After running CTAS (i.e. Daisy View Release 990105) with the seven hour scenario file defined in Section 4.1, a total of 32,162 trajectories were sampled out of 352,742 trajectories. The sampled trajectories were from 2168 flights. Therefore, each one of these flights on average had 14.8 trajectories analyzed. The average duration of extracted trajectories is approximately 27 minutes with a standard deviation of nine minutes. This is lower than the actual trajectory duration built by CTAS, due to the recording process adapted in collecting these trajectories. If a trajectory exists, it is recorded at each HCS track report update (i.e. around every 12 seconds), but the actual duration recorded is only up to 32.5 minutes into the future. This is explained in more detail in Sections 2.5.1 and 4.1. The sampling process reduced the trajectory to the portion where both HCS track data and the predicted trajectory overlap in time, so the duration of the trajectory actually analyzed was reduced to approximately 22 minutes on average with a standard deviation of 11 minutes.

To set the context of the study as defined in Section 2.6.2.1, the counts of the event areas illustrated in Figure 2.6-1 are listed in Table 4.3-1 below. Referring to Figure 2.6-1, the ratio of area "a" to the sum of areas "a" and "c" defines the DST's fraction of valid flights with sampled trajectory prediction. For CTAS, 94.5 percent of the valid aircraft flights had sampled trajectory prediction.

**Table 4.3-1: Valid Track and Trajectory Counts for CTAS Scenario**

| | Valid HCS Flight Data | Insufficient Valid HCS Flight Data | Total Flights With Trajectories |
|---|---|---|---|
| Trajectory | 2168 (a) | 331(b) | 2499 (a +b) |
| Insufficient Trajectory | 127 (c) | | |
| Total Valid Flights | 2295 (a + c) | | |

As defined in Section 2.6.2.2, another statistic useful in setting the context of the study estimates the trajectory prediction coverage over the track time analyzed. For CTAS, each analyzed flight had an average of 87 percent of prediction coverage with a standard deviation of 17.1 percent. Referring to Figure 4.3-1 and the Quantiles in Table 4.3-2, the distribution is relatively spread out with around a 99 percent of prediction coverage value at the ninetieth percentile to a 62 percent of prediction coverage value at the tenth percentile. The distribution forms a 95 percent confidence interval around the mean between 86.3 to 87.7. The maximum ratio of prediction coverage for CTAS was 99.5 percent and the minimum was 4.3 percent.

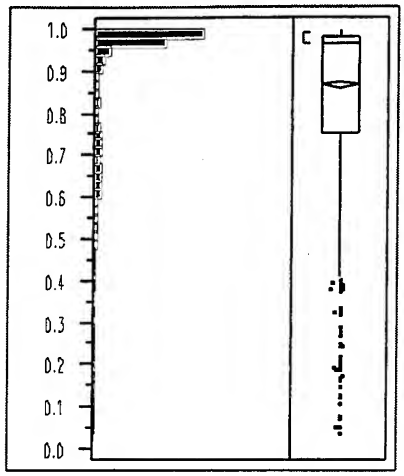


**Figure 4.3-1: CTAS's Distribution of Ratio of Coverage Statistic**

**Table 4.3-2: Quantile Table of Ratio of Prediction Coverage**

| Quantile Labels | Percentiles | Values |
|---|---|---|
| Maximum | 100.0% | 0.99514 |
| | 99.5% | 0.99357 |
| | 97.5% | 0.99121 |
| | 90.0% | 0.98780 |
| Quartile | 75.0% | 0.98253 |
| Median | 50.0% | 0.96952 |
| Quartile | 25.0% | 0.75380 |
| | 10.0% | 0.61926 |
| | 2.5% | 0.45230 |
| | 0.5% | 0.16663 |
| Minimum | 0.0% | 0.04225 |

As described in Section 2.6.2.3, another descriptive value that defines the context of the analysis is the age of the trajectory at the look ahead time of zero. For CTAS, trajectories are built every time the HCS track positions are reported (every 12 seconds). There are situations where trajectories are older, including instances where CTAS did not update the trajectory or when the HCS did not supply a track exactly every 12 seconds. This study's sampled CTAS trajectories have an average trajectory age of approximately 14.6 seconds with a standard deviation of 57 seconds.

As discussed above, CTAS builds trajectories approximately every 12 seconds. The build time in seconds combined with the aircraft identifier string and HCS CID should uniquely represent a particular trajectory. However, there are instances that an aircraft has multiple trajectories with common build times. It was determined that the x and y coordinates within these multiple trajectories were close, but not identical. With the first recorded trajectory often being the correct one, the altitudes did vary significantly. Since these multiple instances occurred infrequently, it was decided to accept the first trajectory, and discard the others. Out of the 352,742 recorded trajectories in this study only 1.8 percent had more than one trajectory with a common build time.

The actual trajectory metrics and sampling process is defined in Section 2.5.1. For this seven hour ZFW scenario, 127,460 samples were taken against the 32,162 trajectories discussed above. Each sample consisted of spatial prediction error measurements including horizontal error, lateral error, longitudinal error, and vertical error. These measures are reported as a function of different look ahead times from zero to 30 minutes in the future, so the trajectory prediction performance includes the spatial prediction errors partitioned by look ahead time. As a review, look ahead time is the predicted time into the future measured from the sample start time for that particular flight. In this study increments of five minutes were used up to a look ahead time of 30 minutes into the future. In other words, if the flight had both a sampled trajectory and sufficient HCS track reports for the full range of time overlap, error measurements would be calculated at zero, five, 10, 15, 20, 25 and 30 minutes into the future for each sample at the current time.

Table 4.3-3 lists the types of statistical analyses that were performed on each of the identified factors. The analyses include either descriptive statistics in which simple tables are presented, inferential statistics in which hypothesis testing of the means and variances were performed, or both. This table also lists whether graphical information was presented with references to the appropriate section number. Inferential statistics and graphical plots (i.e. histograms and quantile tables) were calculated for a subset of the available look ahead times, including zero, 600, 1200, and 1800 seconds. The signed values of the error metrics (e.g. average lateral error) were used for these more exhaustive inferential techniques, since the sample mean acts as a measure of the bias of the trajectory predictions and the standard deviation as a measure of the uncertainty. The absolute value statistics (e.g. average absolute value of lateral error), which are also a useful measure of the uncertainty, have been included in the descriptive statistics reported in Appendix A.2.

**Table 4.3-3: CTAS Analysis Summary**

| Factor For Samples at All Altitudes / Above FL180 | Descriptive Statistics | Inferential Statistics | Histograms / Quantiles | Section Number |
|---|---|---|---|---|
| Look Ahead Time | Yes | Yes | Yes | 4.3.1 |
| Flight Type | Yes | Yes | No | 4.3.2 |
| Phase of Flight Horizontal | Yes | Yes | No | 4.3.3 |
| Phase of Flight Vertical | Yes | Yes | No | 4.3.4 |

## 4.3.1 Analysis of Look ahead time on Trajectory Accuracy

The main factor analyzed in this study was look ahead time, defined in Section 2.2.3.3. One would expect look ahead time to have a statistically significant effect on performance, but the magnitude of the effect is also of interest. A complete table of the spatial prediction error statistics are presented at the look ahead times of zero, 300, 600, 900, 1200, 1500, and 1800 seconds (i.e. zero to 30 minutes) in Appendix A.2. The focus of the following analysis is on the signed error for lateral, longitudinal, horizontal, and vertical errors at the look ahead times of zero, 600, 1200, and 1800 seconds. This analysis includes an example set and summary results of several tables of statistical information provided by the SAS-JMP Software package (SAS Institute, 1995). They are used to evaluate the error data categorized by look ahead time and in the later sections by horizontal and vertical phase of flight. Complete tables for the CTAS data are provided in Appendix A.2. The tables present test results for unequal variance including the Levene Test and the Welch Anova Test. They also include a pairwise means comparison, referred to as the Tukey-Kramer HSD Test. Graphical plots present a comparison of means with

a quantile box, a plot of the means at look ahead time versus error, and a plot of means using the Tukey-Kramer criteria.

#### 4.3.1.1 Samples at all altitudes

The sample variance of the horizontal error from the four look ahead times are compared first by a Levene Statistical Test (Neter, 1996). Referring to Table 4.3-4, this statistical test determines if the hypothesis of equal variances can be rejected. The hypothesis can be rejected in this case, since the variances are significantly different. From Table 4.3-4, the variance of horizontal error is increasing as the look ahead time increases.

**Table 4.3-4: Tests for Equal Variances and Tests for Equal Means**

| Tests that the Variances are Equal (Horizontal Error)[10] | | | | |
|---|---|---|---|---|
| Level (seconds) | Count | Std Dev (nm) | MeanAbsDif to Mean (nm) | MeanAbsDif To Median (nm) |
| 0 | 32609 | 0.85 | 0.25 | 0.20 |
| 600 | 21908 | 4.95 | 3.45 | 3.17 |
| 1200 | 12921 | 8.11 | 5.81 | 5.38 |
| 1800 | 6657 | 11.22 | 8.21 | 7.56 |
| Test | F Ratio | Deg of Freedom | DF Den | Prob>F |
| Levene | 11959.59 | 3 | 74091 | 0.0000 |
| Welch Anova testing Means Equal, allowing Std's Not Equal | | | | |
| | F Ratio | Deg of Freedom | DF Den | Prob>F |
| | 10866.43 | 3 | 18479 | 0.0000 |

Next, the sample mean for each look ahead time is compared. Referring to Table 4.3-4, the Welch test is applied which compares distributions with different variances and sample sizes. It tests whether all the group means are equal. For the horizontal error at different look ahead times, the Welch Test provides evidence to reject the hypothesis that these mean errors are equal. In Figure 4.3-2, diamonds are drawn around each mean representing the 95 percent confidence interval (in this case, the diamonds are flat and look more like heavy lines due to the large range between the group means). These confidence intervals show an increase in the average horizontal error from zero to 1800 seconds look ahead time of approximately 10.6 nautical miles, from 0.3 to 10.9 nautical miles.

[10] Mean Absolute difference to mean and median are intermediate calculations in the Levene Test described in the Appendix A.0.

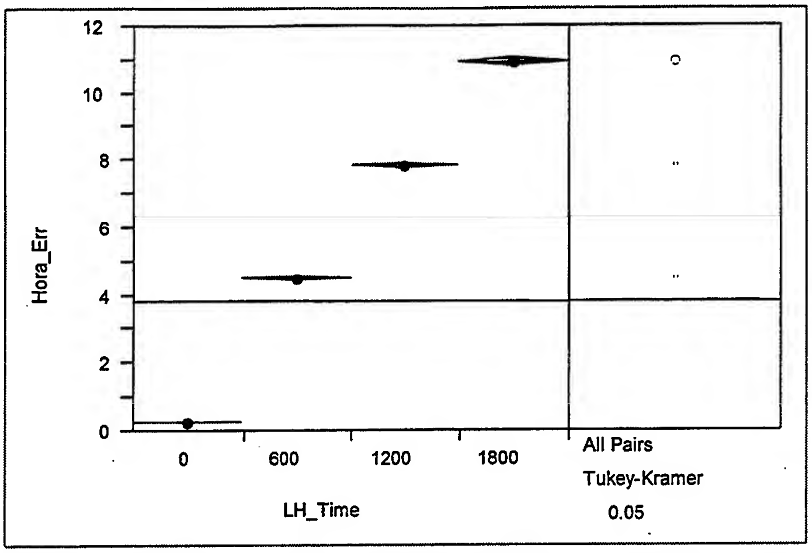


**Figure 4.3-2: Sample Mean Comparison of Horizontal Error at Four Look Ahead Times[11]**

The lower portion of Table 4.3-5 presents the results of a third statistical test, called the Tukey-Kramer Test, that compares all pairs of means and holds the Type I error at 0.05 for the entire test. It has the exact Type I error if the sample sizes are equal, and is conservative if they are not, which is the case in this study (Devore, 1987). The horizontal error at the four look ahead times is significantly difference between all pairs. The Tukey-Kramer Test provides a distance referred to as the Least Significant Difference (LSD)[12] that can be subtracted from the absolute difference of each pair of means. If the result is positive, the absolute difference of the means is greater than LSD, and the pair of means is significantly different. If the result is negative, the LSD is greater, and the pair is not significantly different. The upper portion of Table 4.3-5 lists the pairwise differences of the sample means for the various look ahead times. All these pairwise comparisons of the means of the horizontal error at the different look ahead times were significant.

The right side of Figure 4.3-2 presents a graphical form of the Tukey-Kramer Test. Too small to be drawn in some cases, it constructs circles around the sample means with a diameter approximately equal to the 95 percent confidence interval. However, this interval is expanded to account for the comparison of all pairs. In short, if the circles overlap the means are not considered significantly different; if they do not overlap, the means are considered significantly different. The circles drawn in Figure 4.3-2 are not overlapping at all, illustrating the numerical results that all the means are different.

[11] Normally, the height of the diamond is the length of the confidence interval and the width is proportional to the sample size. In this study, the width has been set equal for all sample sizes.

[12] LSD is proportional to the square root of the sum of the squared product of q* and the standard error of both means being compared. The q* value is a quantile similar to the t value of a Student t distribution but expanded to account for the alpha being held constant for the entire set of comparisons (SAS Institute, 1995).

**Table 4.3-5: Statistical Comparison of All Means (Horizontal Error)**

| Means Comparisons | | | | |
|---|---|---|---|---|
| Dif=Mean[i]-Mean[j] | 1800 | 1200 | 600 | 0 |
| 1800 | 0.0000 | 3.1195 | 6.4127 | 10.6661 |
| 1200 | -3.1195 | 0.0000 | 3.2932 | 7.5466 |
| 600 | -6.4127 | -3.2932 | 0.0000 | 4.3534 |
| 0 | -10.6661 | -7.5466 | -4.3534 | 0.0000 |

| Comparisons for all pairs using Tukey-Kramer HSD | | | | |
|---|---|---|---|---|
| q* = 2.56909 | Alpha=0.05 | | | |
| Abs(Dif)-LSD | 1800 | 1200 | 600 | 0 |
| 1800 | -0.2454 | 2.9059 | 6.2146 | 10.4757 |
| 1200 | 2.9059 | -0.1761 | 3.1361 | 7.3994 |
| 600 | 6.2146 | 3.1361 | -01353 | 4.1298 |
| 0 | 10.4757 | 7.3994 | 4.1298 | -0.1109 |
| Positive values show pairs of means that are Significantly different. | | | | |

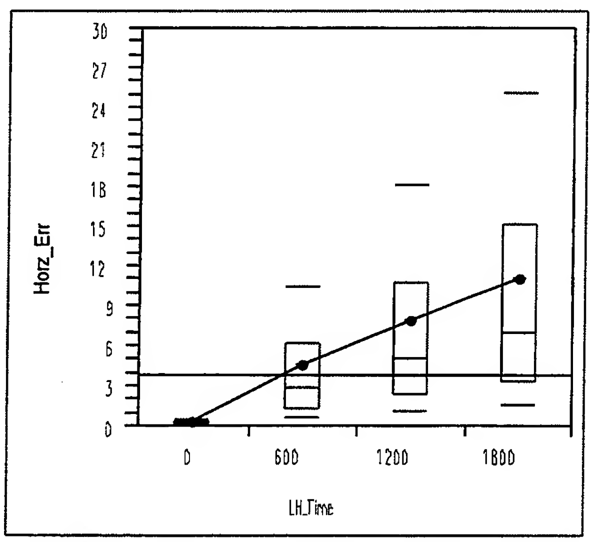


**Figure 4.3-3: Quantile / Mean Comparison of Horizontal Error Vs. LH**

In summary, the mean horizontal error is statistically significant at the look ahead times of zero, 600, 1200, and 1800 seconds. Referring to Figure 4.3-3, the sample means are also increasing as the look ahead time (LH) increases, ranging from a sample mean of 0.28 nautical miles at look ahead zero to 10.94 at 1800 seconds (i.e. 30 minutes). The mean of all observations is drawn as a horizontal line across the entire plot. The median is also increasing from 0.14 nautical miles at zero look ahead time to 6.9 at 1800 seconds. The horizontal lines in Figure 4.3-3's boxes correspond to the 10, 25, 50, 75, and 90 percentiles of the distribution of the sampled horizontal

errors, respectively[13]. Tested statistically with the Levene Test earlier, the box ranges illustrate that the spread of the horizontal error is also increasing as the look ahead time increases.

The analysis continues by examining the lateral, longitudinal, and vertical errors using the same methods described for the horizontal error. The results are summarized in Table 4.3-6 and the means comparisons of the lateral, longitudinal and vertical errors are shown in Figures 4.3-4 through 4.3-6. The descriptive statistics of the absolute values of the four errors are tabulated in Appendix A.2.

**Table 4.3-6: Statistical Results LH 0-30 minutes at All Altitudes**

| Error Type | Levene Test | Welch Test | Tukey-Kramer | Observations |
|---|---|---|---|---|
| Horizontal | Yes | Yes | Yes-all | Means and variance increase with look ahead time (LH). |
| Lateral | Yes | Yes | Yes-5of6 | Only LH 1200 versus LH 1800 not different. Means (all positive) and variance increase with LH except at LH 1200 and 1800. |
| Long. | Yes | Yes | Yes-all | Means and variance increase with LH. |
| Vertical | Yes | Yes | Yes-all | Means all negative and different. Means and variance increase with LH. |

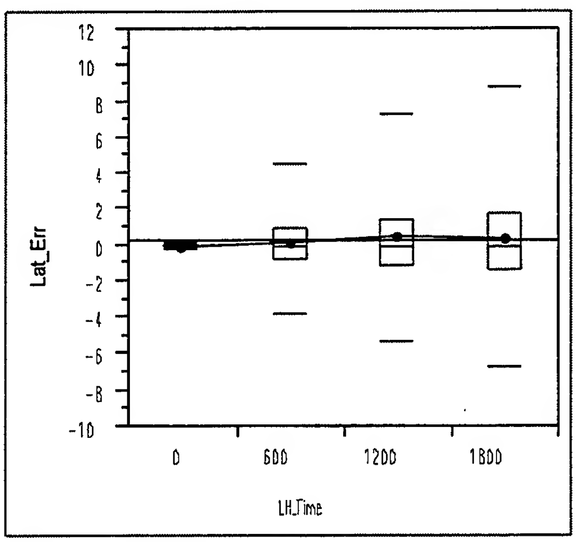


**Figure 4.3-4: Quantile / Mean Comparison of Lateral Error Vs. LH**

[13] The percentiles illustrated in Figure 4.3-3 as horizontal lines and box ends are described in detail in Appendix A.0.

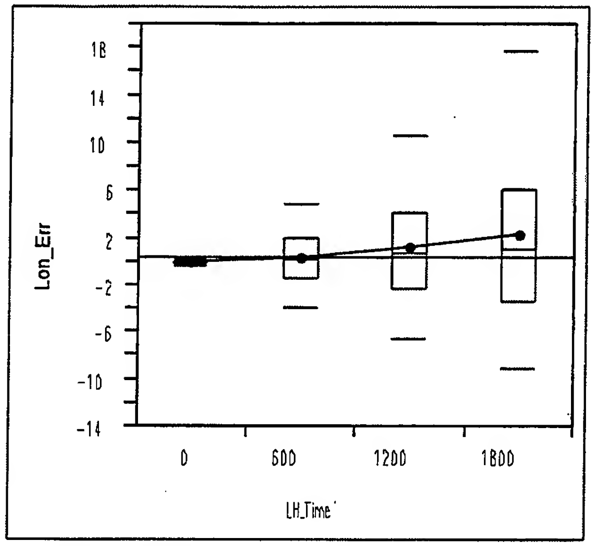


**Figure 4.3-5: Quantile / Mean Comparison of Longitudinal Error Vs. LH**

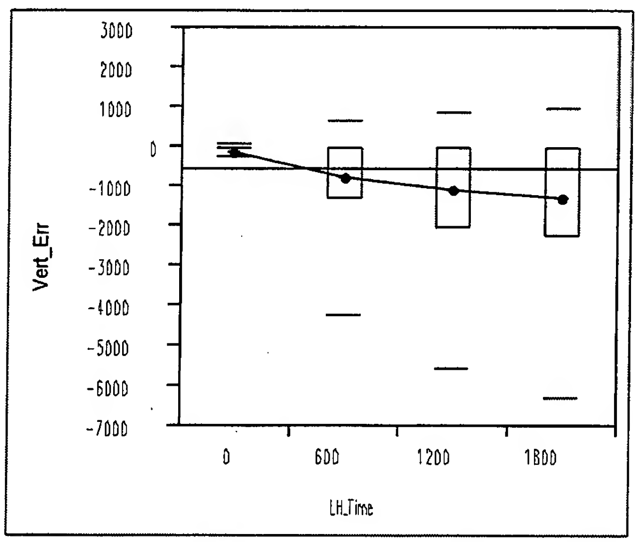


**Figure 4.3-6: Quantile / Mean Comparison of Vertical Error Vs. LH**

### 4.3.1.2 Samples at altitudes above 18,000 feet

For samples at altitudes above 18,000 feet only, the results are summarized in Table 4.3-7. The detailed histograms and statistical tables are located in Appendix A.2.

**Table 4.3-7: Statistical Results LH 0-30 minutes Above 18,000 feet**

| Error Type | Levene Test | Welch Test | Tukey-Kramer | Observations |
|---|---|---|---|---|
| Horizontal | Yes | Yes | Yes-all | Means and variance increase with LH. |
| Lateral | Yes | Yes | Yes-5of6 | Only LH 1200 versus LH 1800 are not different. Variance increases with LH. |
| Long. | Yes | Yes | Yes-5of6 | Only LH 1200 versus LH 1800 are not different. Mean and variance increases with LH. |
| Vertical | Yes | Yes | Yes-5of6 | Means negative. Only LH 1200 versus LH 1800 are not different. LH 600 largest error. Variance increases with LH. |

### 4.3.1.3 Discussion of the effect of look ahead time

In general, look ahead time does have a significant effect on each sample mean, which increases as the look ahead time increases. For horizontal error, the sample means increase over 10 nautical miles from zero to 1800 seconds (i.e. 30 minutes) look ahead time. The variance of the horizontal error also increases with look ahead time with a standard deviation ranging from around one nautical mile to over 11 nautical miles. Lateral and longitudinal errors are exact orthogonal components of the horizontal error, but the dominant source of horizontal error is the longitudinal error. Referring to Figures 4.3-4 and 4.3-5, the average lateral error ranges from zero to 0.46 nautical miles, and the longitudinal error ranges from slightly less than zero to around 2.4 nautical miles. The magnitude increases substantially when looking at the absolute values of the lateral and longitudinal errors. Referring to Appendix A.2, the absolute value (i.e. unsigned) means of lateral error range from 0.1 to 4.9 nautical miles from zero to 30 minutes look ahead time. The absolute value means of longitudinal error range from 0.2 to 8.1 nautical miles from zero to 30 minutes look ahead time. The vertical error mean and variance also increases for zero to 30 minutes look ahead time from –98 to –1270 feet and 790 to 3870 feet, respectively.

For the most part, the analysis of samples above 18,000 feet are consistent with the all altitudes analysis except for vertical error which seems to peak around 10 minutes (600 seconds) look ahead time at around –280 feet and actually gets less at 30 minutes to around –130 feet. The causes for this effect have been left for future analysis.

## 4.3.2 Analysis of Flight Type on Trajectory Accuracy

Flight type is determined by examining the origin and destination airports in a flight plan. The flight type includes four possible levels referred to as overflight, departure, arrival, and internal. Overflight is an aircraft whose origin and destination are outside the particular center's airspace, ZFW in this case. Departures leave an airport inside the center, and arrivals land at an airport inside the center. The internals include flights that have both origin and destination airports inside the center.

The analysis that follows examines whether the means of the trajectory prediction errors of the flight types are significantly different at the four look ahead times of zero, 600, 1200, and 1800 seconds. This analysis focuses on these four look ahead times and flight types against the signed lateral, longitudinal, vertical, and horizontal errors. Appendix A.2 contains a more complete set of look ahead times and also includes the descriptive statistics on the unsigned or absolute values of the errors. Figures 4.3-7 through 4.3-10 plot the sample means for each flight type as a function of look ahead time (LH) where OVR denotes overflights, ARR denotes arrivals, DEP denotes departures, and INR denotes internals.

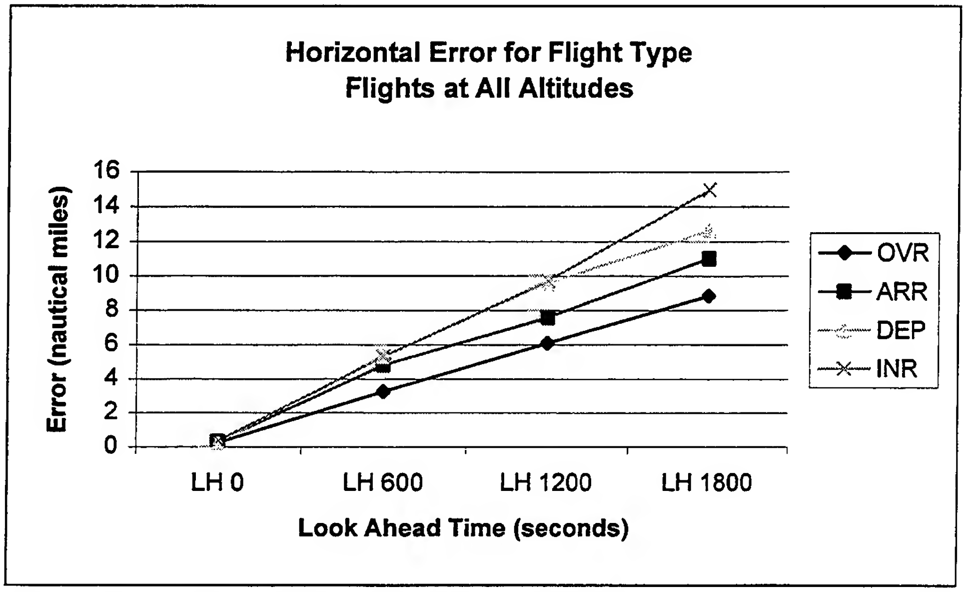


**Figure 4.3-7: Sample Means for Horizontal Error per Flight Type and LH**

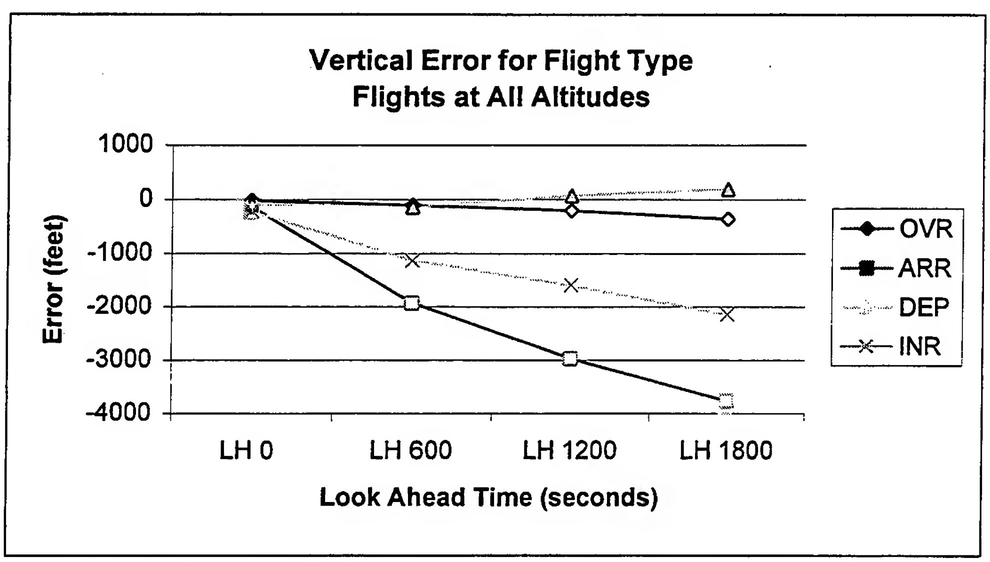


**Figure 4.3-8: Sample Means for Vertical Error per Flight Type and LH**

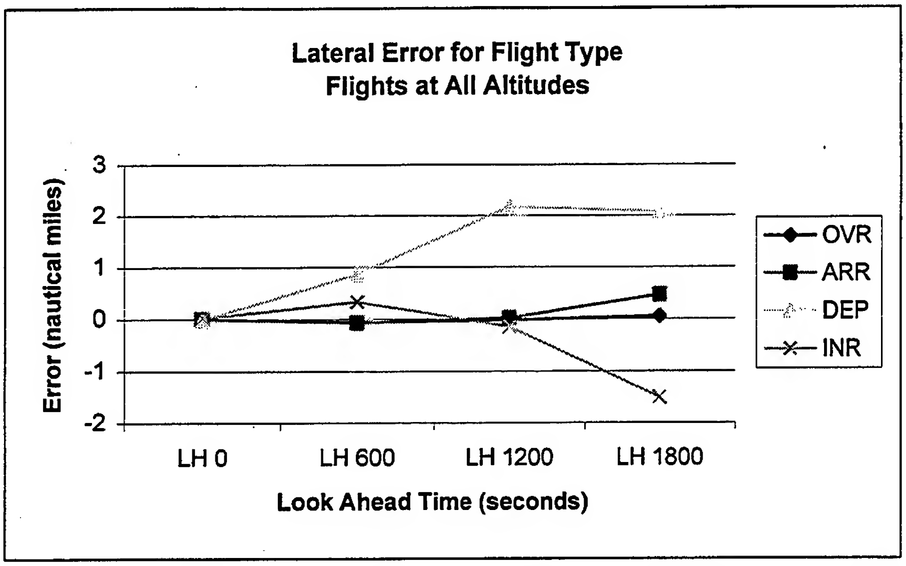


Figure 4.3-9: Sample Means for Lateral Error per Flight Type and LH

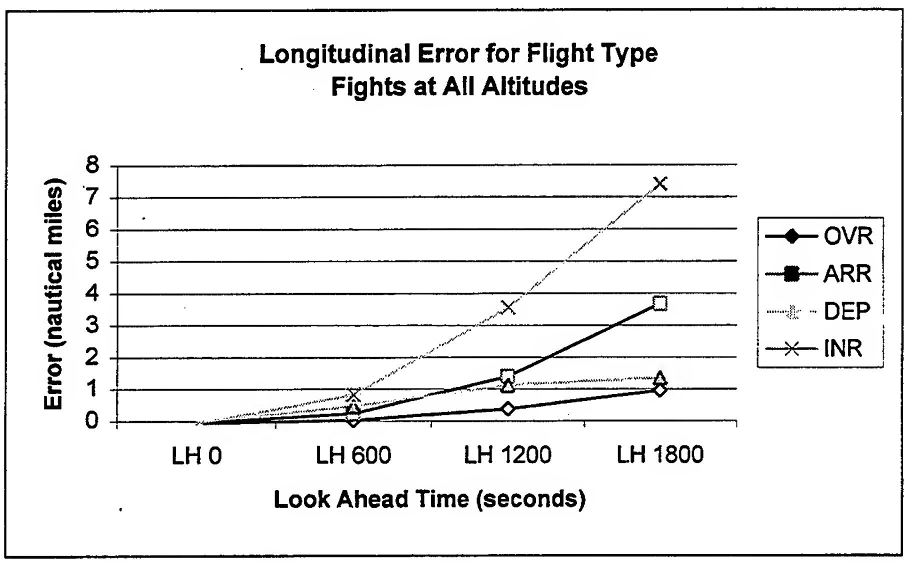


Figure 4.3-10: Sample Means for Longitudinal Error per Flight Type and LH

#### 4.3.2.1 Samples at all altitudes

The results are summarized in Table 4.3-8. The detailed histograms and statistical tables are located in Appendix A.2.

**Table 4.3-8: Statistical Results LH 0-30 minutes at All Altitudes**

| Error Type | Look ahead Time | Levene Test | Welch Test | Tukey-Kramer | Observations |
|---|---|---|---|---|---|
| Horizontal | 0 | Yes | Yes | Yes-4of6 | Internals versus arrivals and departures versus overflights are not different. Internals/arrivals have the largest error. |
| Lateral | 0 | Yes | Yes | Yes-1of6 | Only internals versus departures significantly different. |
| Long. | 0 | Yes | Yes | Yes-1of6 | Only internals versus departures different. |
| Vertical | 0 | Yes | Yes | Yes-all | All means are significantly different statistically but the magnitude is only a few hundred feet. |
| Horizontal | 600 | Yes | Yes | Yes-5of6 | Internals versus departures not different. |
| Lateral | 600 | Yes | Yes | Yes-5of6 | Only arrivals and overflights not different. |
| Long. | 600 | Yes | Yes | Yes-all | Maximum range between means 0.8 nm. |
| Vertical | 600 | Yes | Yes | Yes-5of6 | Departures versus overflights not different. Arrivals having largest mean but internals with largest variance. |
| Horizontal | 1200 | Yes | Yes | Yes-5of6 | Only internals versus departures are not different. |
| Lateral | 1200 | Yes | Yes | Yes-3of6 | Only departures (with a larger error) are significantly different from the others. |
| Long. | 1200 | Yes | Yes | Yes-5of6 | Only departures versus arrivals are not different. Internals have largest error. |
| Vertical | 1200 | Yes | Yes | Yes-all | Arrivals have largest error and departures smallest. |
| Horizontal | 1800 | Yes | Yes | Yes-all | Overflights have the smallest horizontal error, while internals have the largest error. |
| Lateral | 1800 | Yes | Yes | Yes-5of6 | Only arrivals and overflights not different |
| Long. | 1800 | Yes | Yes | Yes-5of6 | Only departures versus overflights are not different. Internals have largest error. |
| Vertical | 1800 | Yes | Yes | Yes-all | Arrivals have largest error. |

### 4.3.2.2 Samples at altitudes above 18,000 feet

The results are summarized in Table 4.3-9. The detailed histograms and statistical tables are located in Appendix A.2.

**Table 4.3-9: Statistical Results LH 0-30 minutes Above 18,000 feet**

| Error Type | Look ahead Time | Levene Test | Welch Test | Tukey-Kramer | Observations |
|---|---|---|---|---|---|
| Horizontal | 0 | Yes | Yes | Yes-3of6 | Only internals versus others are significantly different. |
| Lateral | 0 | Yes | Yes | Yes-3of6 | Only internals versus others are significantly different. |
| Long. | 0 | Yes | Yes | Yes-4of6 | Departures versus overflights and arrivals versus overflights are not different. |
| Vertical | 0 | Yes | Yes | Yes-3of6 | Only internals versus others are different. Internals being slightly larger and positive on average while the others are negative. |
| Horizontal | 600 | Yes | Yes | Yes-all | Internals have largest error and overflights smallest. |
| Lateral | 600 | Yes | Yes | Yes-3of6 | Departures (larger) different than others. |
| Long. | 600 | Yes | Yes | Yes-5of6 | Only arrivals versus overflights not different. Internals have largest error. |
| Vertical | 600 | Yes | Yes | Yes-5of6 | Internals versus departures are not different. Arrivals have largest error. |
| Horizontal | 1200 | Yes | Yes | Yes-5of6 | Arrivals versus overflights are not different. Internals have the largest error |
| Lateral | 1200 | Yes | Yes | Yes-3of6 | Departures have the largest mean and are significantly different from the others. |
| Long. | 1200 | Yes | Yes | Yes-5of6 | Only overflights versus arrivals are not different. Internals have the largest mean. |
| Vertical | 1200 | Yes | Yes | Yes-all | All significantly different, but arrivals have much larger mean error and internals have much larger variance relative to the others. |
| Horizontal | 1800 | Yes | Yes | Yes-4of6 | Arrivals versus overflights and departures and internals are not different. Departures and internals have the larger error. |
| Lateral | 1800 | Yes | Yes | Yes-4of6 | Departures are different from others and overflights versus internals are different as well. |
| Long. | 1800 | Yes | No | No | Only variance is different, with internals having the largest variance. |
| Vertical | 1800 | Yes | Yes | Yes-5of6 | Departures versus internals not different. Arrivals largest mean and internals largest variance. |

#### 4.3.2.3 Discussion of the effect of flight type

In general, flight type has a significant effect on trajectory performance. For horizontal error, overflights have the least errors as look ahead time increases, while internals have the most error ranging from 0.3 to 15 nautical miles from zero to 30 minutes look ahead time, respectively. For vertical error, arrivals seem to have the greatest mean as look ahead time increases, but internals have the largest standard deviation overall. At the lower look ahead times, the vertical error sample means vary little between flight types, but as look ahead time increases they spread out in general very quickly. For example, at look ahead time of 600 seconds or 10 minutes, the arrivals have a mean vertical error of –1923 feet while the overflights have –106 feet mean vertical error.

As far as lateral error, only departures seem to increase considerably as look ahead time increases from –0.01 to 2 nautical miles from 0 to 1800 seconds look ahead time, respectively. Longitudinal error on the other hand does increase as look ahead increases from –0.08 to 7.4 nautical miles on average.. For longitudinal error sample means, the internals dominate from around zero to 6 nautical miles larger than the other flight types on average.

### 4.3.3 Analysis of Horizontal Phase of Flight on Trajectory Accuracy

Horizontal phase of flight is calculated for each HCS track report and extracted for the trajectory accuracy measurements. This factor is categorized into two levels: straight or turn. The PHASE_D program that detects turns, described in Section 2.4.6.1, had its parameters set to protect against noise in the track data. As a result, rapid turns are detected but shallow turns may be missed. A turn is determined by a nine degree angle (or greater) generated by the two segments drawn from the previous position to the current position and the current position to the next position report.

The analysis that follows examines whether the mean of the trajectory prediction error at the two horizontal phases of flight are significantly different statistically at the four look ahead times of zero, 600, 1200, and 1800 seconds. This analysis will focus on these four look ahead times and two phases of flight against the signed lateral, longitudinal, vertical, and horizontal errors. Appendix A.2 contains a more complete set of look ahead times and also includes the descriptive statistics on the unsigned or absolute values of the errors. The following Figures 4.3-11 to 4.3-14 plot the sample means for each horizontal phase of flight as a function of look ahead time (LH), where STR denotes straight and TRN denotes turning.

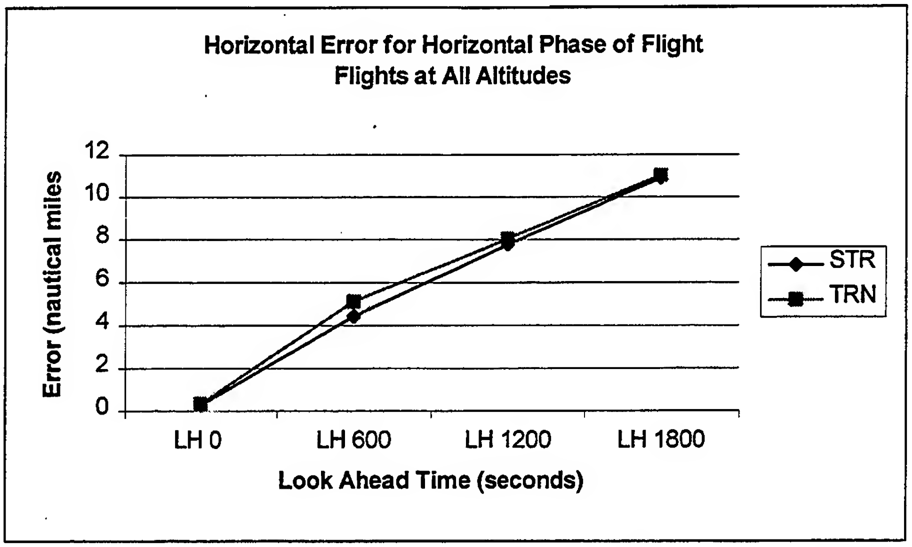


**Figure 4.3-11: Sample Means for Horizontal Error per Horizontal Phase of Flight and LH**

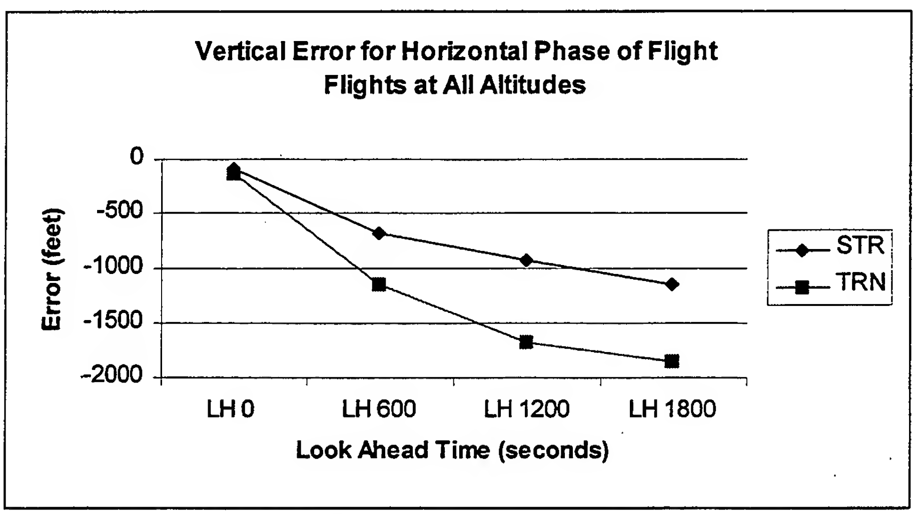


**Figure 4.3-12: Sample Means for Vertical Error per Horizontal Phase of Flight and LH**

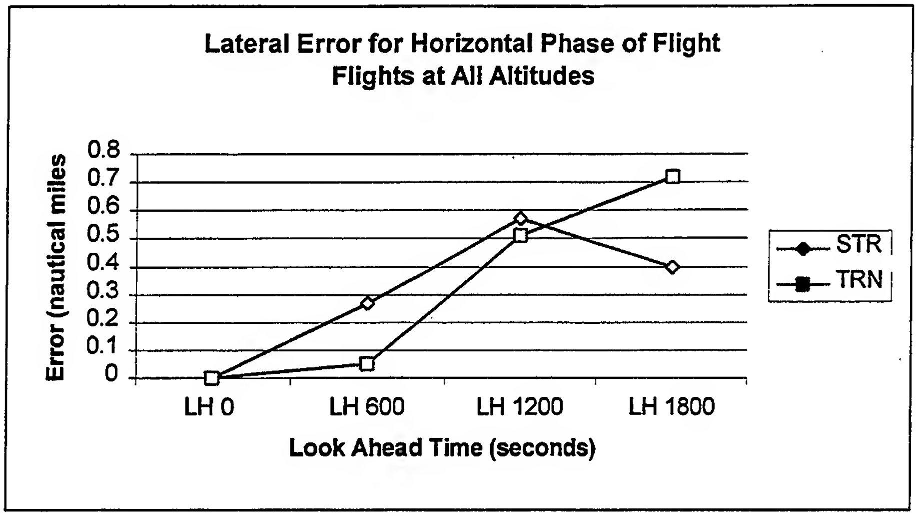


**Figure 4.3-13: Sample Means for Lateral Error per Horizontal Phase of Flight and LH**

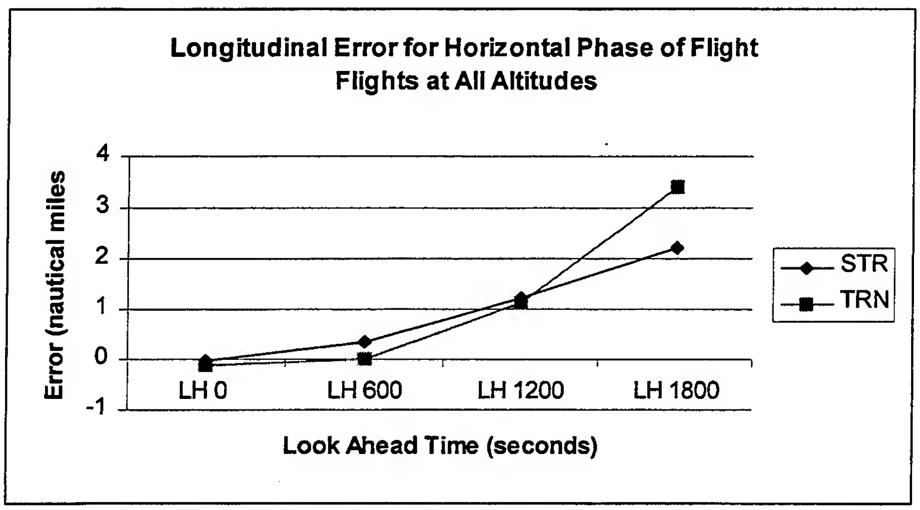


**Figure 4.3-14: Sample Means for Longitudinal Error per Horizontal Phase of Flight and LH**

#### 4.3.3.1 Samples at all altitudes

The results are summarized in Table 4.3-10. The detailed histograms and statistical tables are located in Appendix A.2.

**Table 4.3-10: Statistical Results LH 0-30 minutes at All Altitudes**

| Error Type | Look ahead Time | Levene Test | Welch Test | Tukey-Kramer | Observations |
|---|---|---|---|---|---|
| Horizontal | 0 | Yes | Yes | Yes | Means all different. Turns are larger by 0.07 nautical miles. |
| Lateral | 0 | Yes | No | No | Variance is different only. |
| Long. | 0 | Yes | Yes | Yes | Means both negative with turns larger by 0.07 nautical miles. |
| Vertical | 0 | Yes | Yes | Yes | Means both negative and different. Turns larger by 37 feet. |
| Horizontal | 600 | Yes | Yes | Yes | Turns larger by 0.7 nautical mile. |
| Lateral | 600 | Yes | Yes | Yes | Straight is larger by 0.22 nautical miles. |
| Long. | 600 | Yes | Yes | Yes | Straight is larger by 0.34 nautical miles. |
| Vertical | 600 | Yes | Yes | Yes | Turns larger by 460 feet. |
| Horizontal | 1200 | No | No | No | Not significantly different. |
| Lateral | 1200 | No | No | No | Not significantly different. |
| Long. | 1200 | Yes | No | No | Only variance significantly different. |
| Vertical | 1200 | Yes | Yes | Yes | Turns larger by 740 feet. |
| Horizontal | 1800 | No | No | No | Not significantly different. |
| Lateral | 1800 | No | No | No | Not significantly different. |
| Long. | 1800 | No | Yes | Yes | Turns larger around 1.2 nautical miles. |
| Vertical | 1800 | Yes | Yes | Yes | Turns larger by 700 feet. |

#### 4.3.3.2 Samples at altitudes above 18,000 feet

The results are summarized in Table 4.3-11. The detailed histograms and statistical tables are located in Appendix A.2.

**Table 4.3-11: Statistical Results LH 0-30 minutes Above 18,000 feet**

| Error Type | Look ahead Time | Levene Test | Welch Test | Tukey-Kramer | Observations |
|---|---|---|---|---|---|
| Horizontal | 0 | Yes | Yes | Yes | Turns larger by 0.12 nautical miles. |
| Lateral | 0 | Yes | No | No | Only variance significantly different. |
| Long. | 0 | Yes | Yes | Yes | Turns larger by 0.09 nautical miles. |
| Vertical | 0 | Yes | Yes | Yes | Different but turns larger by only 30 feet. |
| Horizontal | 600 | Yes | Yes | Yes | Turns larger by 1 nautical mile. |
| Lateral | 600 | Yes | No | Yes | Only variance significantly different. T-K Test does provide evidence that means are different but Welch Test with p-value of 0.08 has more power to differentiate. |
| Long. | 600 | Yes | Yes | Yes | Turns larger by 0.23 nautical miles. |
| Vertical | 600 | Yes | Yes | Yes | Turns larger by 500 feet. |
| Horizontal | 1200 | No | No | No | Not significantly different. |
| Lateral | 1200 | No | No | No | Not significantly different. |
| Long. | 1200 | No | No | No | Not significantly different. |
| Vertical | 1200 | Yes | Yes | Yes | Turns larger by 700 feet. |
| Horizontal | 1800 | Yes | No | No | Only variance significantly different. |
| Lateral | 1800 | No | No | No | Not significantly different. |
| Long. | 1800 | No | No | No | Not significantly different. |
| Vertical | 1800 | Yes | Yes | Yes | Turns larger by 500 feet. |

#### 4.3.3.3 Discussion of the effect of Horizontal Phase of Flight

In general for horizontal error, the phase of flight in the horizontal dimension is significant only at the lower look ahead times. As the look ahead times get larger, the difference between samples at turns or straight paths becomes insignificant. However, for vertical error the difference is significant and consistently higher at all look ahead times for turns compared to straight samples. It also becomes larger as look ahead time increases. For both the horizontal and vertical dimensions, the differences between turning and straight samples is still rather small (i.e. less one nautical mile for horizontal error and 700 feet for vertical error). These small magnitudes may be caused by the insensitivity in characterizing a turn. The track points are only evaluated at large turns (around nine degrees) to protect against noise in the data, making it less powerful in detecting small turns. There has also been some discussion on the need for analysis a small distance before and after the actual turn. The current technique for determining an aircraft is turning is not sufficiently robust in filtering out the noise of the HCS track reports nor can it examine the straight path around the turn. As a result, the statistical analysis of the effect of turns should be interpreted advisedly and the algorithm will be revisited in the future.

### 4.3.4 Analysis of Vertical Phase of Flight on Trajectory Accuracy

Similar to horizontal phase of flight, vertical phase of flight is calculated for each interpolated HCS track report and extracted for the trajectory accuracy measurements. Vertical phase of flight is categorized into three categories: level, ascending, or descending. The track points are only labeled as climbing or descending for reasonably large climbs and descents to protect against noise in the position data, but this also prevents detection of low rate climbs and descents (i.e. smaller than 900 feet per minute). A climb or descent is determined by calculating the difference in altitude between the current interpolated track position and the next track position. If the absolute difference is less than 150 feet, the current position of the aircraft is considered in level flight, otherwise the aircraft is in a climb or descent depending on the direction up or down. Since the track positions are interpolated at 10 second intervals, the required gradient for the climbing or descending aircraft is greater than or equal to 15 feet per second or 900 feet per minute. The phase of flight algorithm is described in detail in Section 2.4.6.

The analysis that follows examines whether the mean of the trajectory prediction error at the three vertical phases of flight are significantly different statistically at the four look ahead times of zero, 600, 1200, and 1800 seconds. This analysis focuses on these four look ahead times and three phases of flight against the signed lateral, longitudinal, vertical, and horizontal errors. Appendix A.2 contains a more complete set of look ahead times and also includes the descriptive statistics on the unsigned or absolute values of the errors. The following Figures 4.3-15 to 4.3-18 plot the sample means for each vertical phase of flight as a function of look ahead time (LH), where LEV denotes level flight, ASC denotes ascending and DES denotes descending.

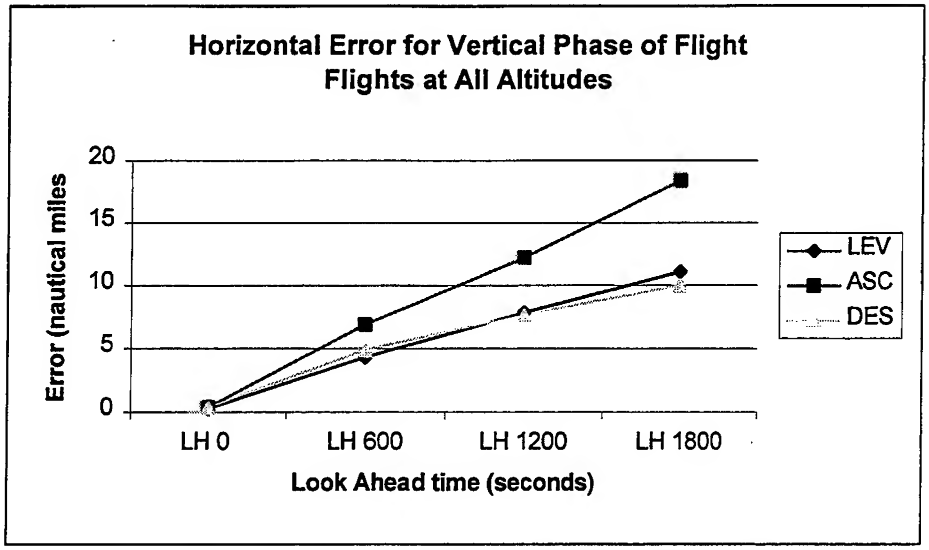


**Figure 4.3-15: Sample Means for Horizontal Error per Vertical Phase of Flight and LH**

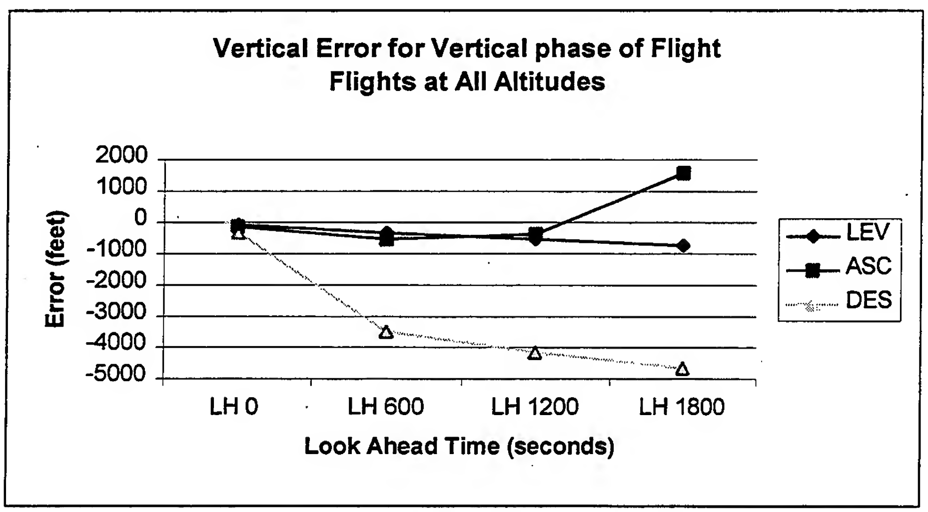


**Figure 4.3-16: Sample Means for Vertical Error per Vertical Phase of Flight and LH**

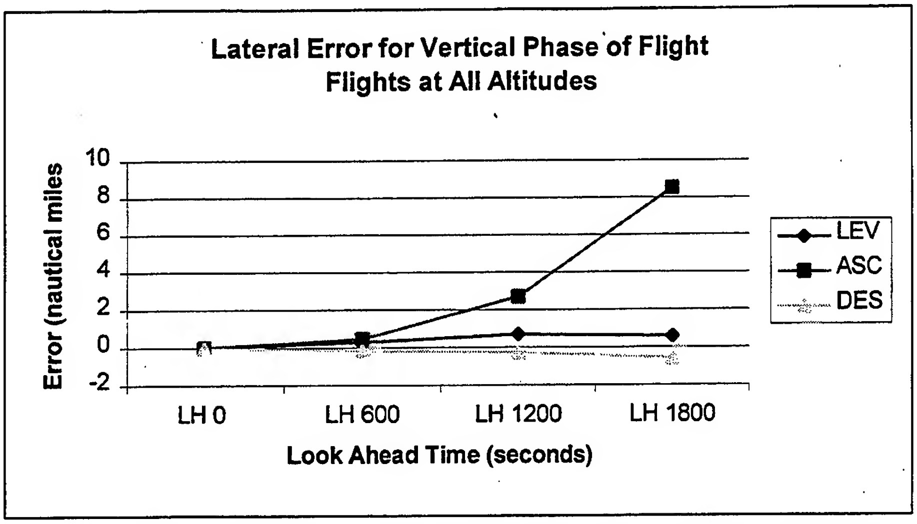


**Figure 4.3-17: Sample Means for Lateral Error per Vertical Phase of Flight and LH**

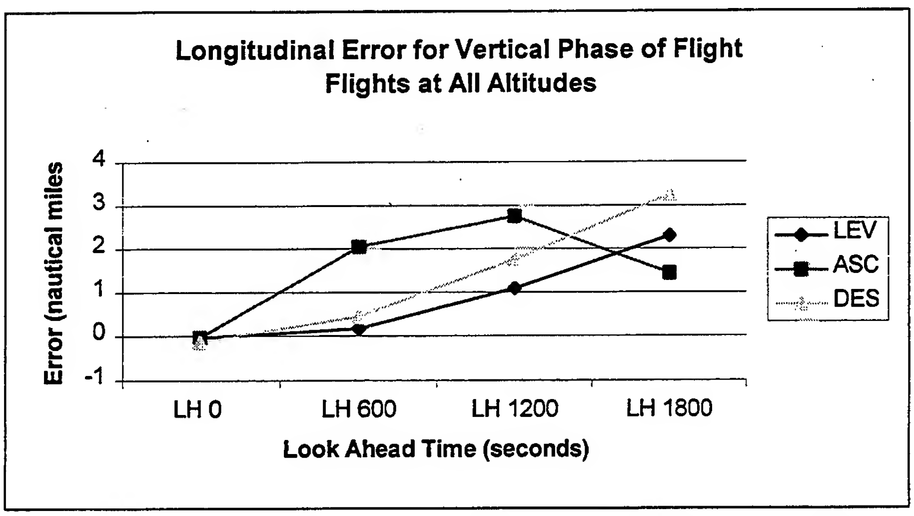


**Figure 4.3-18: Sample Means for Longitudinal Error per Vertical Phase of Flight and LH**

#### 4.3.4.1 Samples at all altitudes

The results are summarized in Table 4.3-11. The detailed histograms and statistical tables are located in Appendix A.2.

**Table 4.3-12: Statistical Results LH 0-30 minutes at All Altitudes**

| Error Type | Look ahead Time | Levene Test | Welch Test | Tukey-Kramer | Observations |
|---|---|---|---|---|---|
| Horizontal | 0 | Yes | Yes | Yes-2of3 | Level different from others. Ascent and descent same, larger error. |
| Lateral | 0 | Yes | No | No | Only variance significantly different. |
| Long. | 0 | Yes | Yes | Yes-2of3 | Only ascent versus level not different. |
| Vertical | 0 | Yes | Yes | Yes | Descent largest error, -322 feet. |
| Horizontal | 600 | Yes | Yes | Yes-all | Level has largest error at 6.92 nautical miles (nm). |
| Lateral | 600 | Yes | Yes | Yes-2of3 | Only ascent versus level not different. |
| Long. | 600 | Yes | Yes | Yes-all | Ascent has largest error, 2 nm. |
| Vertical | 600 | Yes | Yes | Yes-all | Descent has largest error, -3486 feet. |
| Horizontal | 1200 | Yes | Yes | Yes-2of3 | Only level versus descent not different. |
| Lateral | 1200 | Yes | Yes | Yes-all | Ascent has largest error at 2.7 nm. |
| Long. | 1200 | No | Yes | Yes-1of3 | Only descent versus level are different. |
| Vertical | 1200 | Yes | Yes | Yes-2of3 | Only level versus ascent not different. |
| Horizontal | 1800 | Yes | Yes | Yes-all | Ascent has largest error, 18.4 miles. Inconclusive with ascent only 13 samples. |
| Lateral | 1800 | Yes | Yes | Yes-all | Ascent has largest error, 8.5 miles. Inconclusive with ascent only 13 samples. |
| Long. | 1800 | Yes | No | No | Only variance significantly different. Inconclusive with ascent only 13 samples. |
| Vertical | 1800 | Yes | Yes | Yes-2of3 | Only level versus ascent not different. Inconclusive with ascent only 13 samples. |

### 4.3.4.2 Samples at altitudes above 18,000 feet

The results are summarized in Table 4.3-12. The detailed histograms and statistical tables are located in Appendix A.2.

**Table 4.3-13: Statistical Results LH 0-30 minutes Above 18,000 feet**

| Error Type | Look ahead Time | Levene Test | Welch Test | Tukey-Kramer | Observations |
|---|---|---|---|---|---|
| Horizontal | 0 | Yes | Yes | Yes-all | Ascent has largest error, 0.4 nm. |
| Lateral | 0 | Yes | No | No | Only variance significantly different. |
| Long. | 0 | Yes | Yes | Yes-2of3 | Only level versus ascent not different. |
| Vertical | 0 | Yes | Yes | Yes-2of3 | Only level versus ascent not different. |
| Horizontal | 600 | Yes | Yes | Yes-all | Ascent has largest error, 7 nm. |
| Lateral | 600 | Yes | Yes | Yes-2of3 | Only level versus ascent not different. |
| Long. | 600 | Yes | Yes | Yes-2of3 | Only level versus descent not different. |
| Vertical | 600 | Yes | Yes | Yes-all | Descent has largest error, -3033 feet. |
| Horizontal | 1200 | Yes | Yes | Yes-2of3 | Only level versus descent not different. Ascent has larger error at 12.3 nm. |
| Lateral | 1200 | Yes | Yes | Yes-2of3 | Only level versus ascent not different. |
| Long. | 1200 | Yes | No | No | Only variance significantly different. |
| Vertical | 1200 | Yes | Yes | Yes-2of3 | Only level versus ascent not different. |
| Horizontal | 1800 | Yes | Yes | Yes-all | Ascent has largest error, 18.4 nm. |
| Lateral | 1800 | Yes | Yes | Yes-all | Ascent has largest error, 8.5 nm. |
| Long. | 1800 | Yes | No | No | Only variance significantly different. |
| Vertical | 1800 | Yes | Yes | Yes-all | Descent has largest error, -3745 feet. |

### 4.3.4.3 Discussion of the effect of Vertical Phase of Flight

The vertical phase of flight does have a significant effect on the spatial errors. In particular, aircraft in ascent have samples with the largest horizontal mean error as look ahead time increases. From Figure 4.3-15, the sample means for ascending phase of flight range from 0.4 nautical miles to around 12 nautical miles from zero to 20 minutes look ahead time, respectively. There are only a few samples (i.e. 13 sample points) available at the larger look ahead times for ascending flight, making the results inconclusive for ascents at 30 minutes (1800 seconds) look ahead time.

The vertical phase of flight has a significant effect on vertical error as well. The descending phase of flight has the largest effect on the mean error, although the ascending samples have the largest standard deviation or variance at the lower look ahead times. Referring to Figure 4.3-16, the sample mean for descending phase of flight, which is a measure of the prediction bias, shows a decreasing (becomes more negative) average vertical error as look ahead time increases. Therefore, the trajectory prediction tends to overestimate the altitude. For aircraft in descent at look ahead times from five minutes to 30 minutes, the CTAS trajectory tends to predict either the altitude lagging (i.e. not descending fast enough), leaving the predicted altitude above the actual, or it may have lagged on its predicted location of the top of descent point, which has a similar effect.

The uncertainty of the prediction on the vertical dimension is measured by the standard deviation for each vertical phase of flight. Referring to Appendix A.2, the lower look ahead times between zero and five minutes show ascending phase of flight dominates with ranges of the standard deviation between 1400 and 4300 feet. For the larger look ahead times above five minutes, the descending phase of flight samples dominate with standard deviations ranging from 3500 to 4800 feet.

# 5. Summary

This report presents the results of an independent analysis of the accuracy of the trajectory modelers implemented in the URET and CTAS prototypes. These results are based on the completion of the first phase of a planned two phased effort. As originally envisioned, efforts during Phase 1 would develop a generic methodology to measure trajectory prediction accuracy which would be validated by applying it to CTAS and URET at their currently adapted sites. In Phase 2, the methodology would be applied to URET and CTAS systems that had been adapted to a common site and supplied with the same scenario. As such, the results from Phase 2 would have provided a common set of results based on the same site and scenario, allowing a comparison to be made of the two trajectory modelers, in support of research into the performance requirements for a common en route trajectory model. Unfortunately, due to funding cuts ACT-250 was only able to complete Phase 1. The results from this phase do provide the FAA with an independent set of scenario-based trajectory accuracy statistics for each DST, however, they cannot be used to compare the two DSTs due to the confounding site-specific factors.

A methodology was developed and CTAS and URET were measured based on one scenario each from their currently adapted sites (Fort Worth and Indianapolis, respectively). Both scenarios were approximately seven to 7.5 hours in duration and contained about 2500 flights. In the URET scenario from Indianapolis Center (ZID) used for this study, approximately 45 percent of the flights were overflights, 27 percent were departures, 25 percent were arrivals, and 3 percent were denoted "internals". For the CTAS scenario from Fort Worth Center (ZFW), the flight type mix was very different with approximately 13 percent of the flights being internals, 31 percent arrivals, 30 percent departures, and only 26 percent overflights. The differences in the scenarios for the flight type highlight the major differences between the scenarios and are one example why the Phase 1 results can only be reviewed individually.

The evaluation methodology took the point of view of the Air Traffic Controller using the DST. That is, a Controller viewing the aircraft predicted position data on the graphical user interface of the DST would ask how accurate the predictions were into the future, e.g., 5 minutes, 10 minutes, 20 minutes, and beyond. The Controller is not necessarily interested in the interior workings of the tool, e.g., how recently the tool made its currently valid predictions, but rather how accurate the prediction is now, and into the future. Built upon this conceptual point of view of the user, a sampling process was used to obtain the measurement data. At selected times the actual position of the aircraft was obtained from the HCS radar track data and was compared with the position of the aircraft predicted by the tool.

The Phase 1 study measured the spatial error between trajectory predictions versus the HCS track position reports, which were assumed to be the ground truth location of the aircraft. The spatial error consisted of horizontal and vertical errors. The horizontal error was further partitioned into two geometric components, lateral and longitudinal errors, representing the cross track and along track prediction errors. These errors were calculated for trajectories where both HCS track data and the DST trajectory overlapped in time. In a sense, a DST could incur higher accuracy with small trajectory errors if it selectively built trajectories; however, in this study both CTAS and URET made predictions on most of the available valid flights (aircraft movements that have both flight plan and verified track position information). For URET, 97 percent of the flights were analyzed and for CTAS 95 percent were analyzed.

The focus of the analysis was on the overall trajectory accuracy of each DST, not on individual errors. A statistical analysis was performed on the overall accuracy of the two modelers in their

respective Centers with their respective scenarios. This analysis was performed on approximately 17,000 URET trajectories and 32,000 CTAS trajectories. The spatial errors have been summarized with descriptive statistics in the horizontal, lateral, longitudinal, and vertical dimensions as a function of look ahead time. Inferential statistics were performed to determine whether specific factors (i.e., look ahead time, flight type, horizontal phase of flight, and vertical phase of flight) had a significant effect on these performance statistics.

For URET, the sample means for the horizontal error, as a function of look ahead time, range from 1.2 to 10.2 nautical miles for 0 to 30 minutes look ahead time. The sample standard deviations range from 1.1 to 10.9 nautical miles. For CTAS, the sample means for the horizontal error as a function of look ahead time, range from 0.3 to 10.9 nautical miles for 0 to 30 minutes look ahead time. The sample standard deviations range from 0.9 to 11.2 nautical miles. For both URET and CTAS, the average and standard deviation of the horizontal error increases as look ahead time increases. In other words, the horizontal uncertainty of the trajectory predictions analyzed in this study increased by about 10 nautical miles on average as look ahead increased from zero to 30 minutes into the future.

As previously stated, while the Phase 1 analysis cannot be used to compare the URET and CTAS trajectory modelers, the results do provide the FAA with an independent scenario based set of trajectory accuracy measurements for each DST. All of the data from this study is stored in a large set of Oracle database tables in the WJHTC TFM Laboratory. This data can be made available to other members of the FAA community who may wish to analyze other factors, or answer other questions of interest, related to the trajectory prediction accuracy of URET and CTAS upon formal request to ACT-250. In addition, a generic methodology has been developed for the performance measurement of a common trajectory model. In FY99, this methodology and the parsing tools developed in this study will be applied to the development of DSR Workload Scenarios to be used for URET CCLD accuracy testing. With the planned adaptation of URET and CTAS to a common site, tentatively scheduled to occur in 2001, and anticipated funding availability in FY01, ACT-250 hopes to resume work on the proposed Phase 2 study to further address the FAA's efforts to determine the feasibility of a common en route trajectory model.

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# List of Acronyms

| | |
|---|---|
| ACID | Aircraft Identification |
| ACT-250 | WJHTC ATM Engineering, Research and Evaluation Branch |
| ARR | Arrival |
| ARTCC | Air Route Traffic Control Center |
| ASC | Ascending |
| ATC | Air Traffic Control |
| ATM | Air Traffic Management |
| BOD | Bottom of Descent |
| CAASD | Center for Advanced Aviation System Development |
| CCLD | Core Capability Limited Deployment |
| CID | Computer Identification |
| CLT | Central Limit Theorem |
| CPP | CTAS Parser Program |
| CTAS | Center-TRACON Automation System |
| DEP | Departure |
| DES | Descending |
| DST | Decision Support Tool |
| ENR | En Route |
| FAA | Federal Aviation Administration |
| FL | Flight Level |
| FFP1 | Free Flight Phase 1 |
| FP | Flight Plan |
| GIM | General Purpose Output Interface Module |
| HCS | Host Computer System |
| HSD | Honestly Significant Difference |
| IAIPT | Interagency ATM Integrated Product Team |
| IFR | Instrument Flight Rules |
| INR | Internal |
| JRPD | Joint Research Project Description |
| LEV | Level flight |
| LH | Look ahead time |
| LSD | Least Significant Difference |
| MTR | Monitor Test and Recording |
| NAS | National Airspace System |
| NASA | National Aeronautics and Space Administration |
| nm | Nautical Mile |
| OVR | Overflight |
| RHCMP | Reverse Host Converge/Merge Process |
| SAS | Statistical Analysis Systems |
| SID | Standard Instrument Departure |
| ZQL | Standard Query Language |
| STAR | Standard Arrival Route |
| STD | Standard Deviation |
| STR | Straight |
| TFM | Traffic Flow Management |
| TJS | Trajectory Sampling |
| TOD | Top of Descent |
| TRN | Turning |

| | |
|---|---|
| URET | User Request Evaluation Tool |
| WJHTC | William J. Hughes Technical Center |
| ZFW | Fort Worth ARTCC |
| ZID | Indianapolis ARTCC |
| ZKC | Kansas City ARTCC |
| ZOB | Cleveland ARTCC |

# Trajectory Prediction Accuracy Report: User Request Evaluation Tool (URET)/ Center-TRACON Automation System (CTAS

## APPENDIX A: Detailed Listing of Analysis Data

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May 1999

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# List of Figures

# APPENDIX A

## A.0 Introduction to Appendix

This Appendix is a supplement to *Trajectory Prediction Accuracy Report: User Request Evaluation Tool (URET)/Center-TRACON Automation System (CTAS), DOT/FAA/CT-TN99/10.* Appendix A contains summary tables, charts and statistical tests selected to evaluate the URET and CTAS trajectory modeling tools. Section A.0.1 provides a summary and Section A.0.2 a description of the summary tables and the statistical charts in the Appendix A. Section A.0.3 describes the JMP charts. Section A.0.4 describes the statistical tests used in the analysis. Section A.0.5 provides a list of references for Appendix A.0.

### *A.0.1 Appendix Layout*

The Appendix A is ordered by trajectory modeler and by the four categories analyzed in the report – look ahead time, flight type, horizontal and vertical phase of flight. Table A.0-1 shows the Appendix A layout and the charts and statistical tests for each section.

**Table A.0-1: Appendix Tables and Statistical Tests by Trajectory Modeler**

| Section A.1 URET | | Section A.2 CTAS | |
|---|---|---|---|
| A.1.1 | Look Ahead Time<br>Summary Tables<br>Statistical Tests<br>Box Plots and Histograms | A.2.1 | Look Ahead Time<br>Summary Tables<br>Statistical Tests<br>Box Plots and Histograms |
| A.1.2 | Flight Type<br>Summary Table<br>Statistical Tests | A.2.2 | Flight Type<br>Summary Table<br>Statistical Tests |
| A.1.3 | Horizontal Phase of Flight<br>Summary Table<br>Statistical Tests | A.2.3 | Horizontal Phase of Flight<br>Summary Table<br>Statistical Tests |
| A.1.4 | Vertical Phase of Flight<br>Summary Table<br>Statistical Tests | A.2.4 | Vertical Phase of Flight<br>Summary Table<br>Statistical Tests |

## *A.0.2 Description of Summary Tables and Statistical Tests*

*Summary Tables*

Each Appendix A section begins with a set of tables providing summary statistics for the four basic errors analyzed in the report – horizontal, lateral, longitudinal and vertical prediction error. Statistics include the sample quantity, error mean, error standard deviation, maximum and minimum values for the four errors and their absolute values as well. Figure A.0-1 shows the summary table format. This specific table is for the look ahead time category and the column headers are look ahead time in increments of 300 seconds. Other summary tables include a second set of group categories listed in the column headers. The column header for flight type has the categories OVR (over flights), ARR (arrivals), DEP (departures), and INR (internals). The column header for the horizontal phase of flight table has Turn (TRN) and Straight (STR). The table for vertical phase of flight has Level (LEV), Ascent (ASC), and Descent (DES). The left hand column of each summary table is grouped by error statistic. The order from top to bottom is horizontal error, lateral error, absolute lateral error, longitudinal error, absolute longitudinal error, vertical error, absolute vertical error, and slant range error. The order of statistics within each error group is average error, standard deviation, maximum and minimum error.

| Look Ahead Time (sec) | 0 | 300 | 600 | 900 | 1200 | 1500 | 1800 |
|---|---|---|---|---|---|---|---|
| Sample Quantity | 35928 | 29799 | 23964 | 18529 | 13836 | 9678 | 6444 |
| Avg. Horz. Error | 1.2 | 3.16 | 5.11 | 6.82 | 8.25 | 9.36 | 10.17 |
| Stddev. Horz. Error | 1.08 | 3.4 | 5.47 | 7.28 | 8.89 | 10.1 | 10.9 |
| Max. Horz. Error | 42.39 | 84.31 | 125.68 | 167.79 | 173.62 | 156.35 | 169.84 |
| Min. Horz. Error | 0 | 0.01 | 0.02 | 0.02 | 0.02 | 0.01 | 0.04 |
| Avg. Lat. Error | -0.02 | -0.1 | -0.17 | -0.21 | -0.21 | -0.24 | -0.22 |
| Stddev. Lat. Error | 1.34 | 3.64 | 5.43 | 6.98 | 8.41 | 9.49 | 10.06 |
| Max. Lat. Error | 32.23 | 65.49 | 97.45 | 129.48 | 134.87 | 120.34 | 117.09 |
| Min. Lat. Error | -16 | -39.47 | -61.74 | -94.55 | -124.94 | -143.49 | -155.99 |
| Avg. Abs. Lat. Error | 0.87 | 1.98 | 2.86 | 3.59 | 4.16 | 4.58 | 4.74 |
| Stddev. Abs. Lat. Error | 1.02 | 3.06 | 4.62 | 5.99 | 7.31 | 8.32 | 8.87 |
| Max. Abs. Lat. Error | 32.23 | 65.49 | 97.45 | 129.48 | 134.87 | 143.49 | 155.99 |
| Min. Abs. Lat. Error | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Avg. Long. Error | -0.02 | 0.09 | 0.36 | 0.52 | 0.69 | 0.79 | 0.88 |
| Stddev. Long. Error | 0.91 | 2.87 | 5.13 | 7.11 | 8.71 | 9.94 | 10.96 |
| Max. Long. Error | 11.93 | 25.52 | 91.73 | 94.25 | 96.16 | 97.63 | 98.01 |
| Min. Long. Error | -27.53 | -65.39 | -79.36 | -106.71 | -109.33 | -99.82 | -78.53 |
| Avg. Abs. Long. Error | 0.61 | 1.88 | 3.31 | 4.6 | 5.73 | 6.64 | 7.42 |
| Stddev. Abs. Long. Error | 0.67 | 2.17 | 3.94 | 5.44 | 6.59 | 7.43 | 8.12 |
| Max. Abs. Long. Error | 27.53 | 65.39 | 91.73 | 106.71 | 109.33 | 99.82 | 98.01 |
| Min. Abs. Long. Error | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Avg. Vert. Error | 49.36 | -6.95 | -126.58 | -183.49 | -200.71 | -273.61 | -327.15 |
| Stddev. Vert. Error | 662.94 | 1613.04 | 1960.92 | 2006.64 | 2113.7 | 2218.71 | 2298.25 |
| Max. Vert. Error | 36817 | 34817 | 28933 | 30746.5 | 37473.73 | 38907.87 | 31668.16 |
| Min. Vert. Error | -6824.15 | -12626.9 | -15373.8 | -16419.3 | -15900 | -17219.3 | -15800 |
| Avg. Abs. Vert. Error | 204.12 | 735.26 | 917.9 | 945.74 | 990.05 | 1065.64 | 1099.49 |
| Stddev. Abs. Vert. Error | 632.66 | 1435.73 | 1737.43 | 1779.27 | 1878.23 | 1965.15 | 2044.49 |
| Max. Abs. Vert. Error | 36817 | 34817 | 28933 | 30746.5 | 37473.73 | 38907.87 | 31668.16 |
| Min. Abs. Vert. Error | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Avg. Slant Range Error | 1.21 | 3.18 | 5.12 | 6.84 | 8.26 | 9.37 | 10.18 |
| Stddev. Slant Range Error | 1.09 | 3.39 | 5.46 | 7.27 | 8.88 | 10.09 | 10.89 |
| Max. Slant Range Error | 42.39 | 84.34 | 125.72 | 167.86 | 173.7 | 156.48 | 169.84 |
| Min. Slant Range Error | 0 | 0.01 | 0.02 | 0.03 | 0.02 | 0.01 | 0.04 |

**Figure A.0-1: Example of Summary Table**

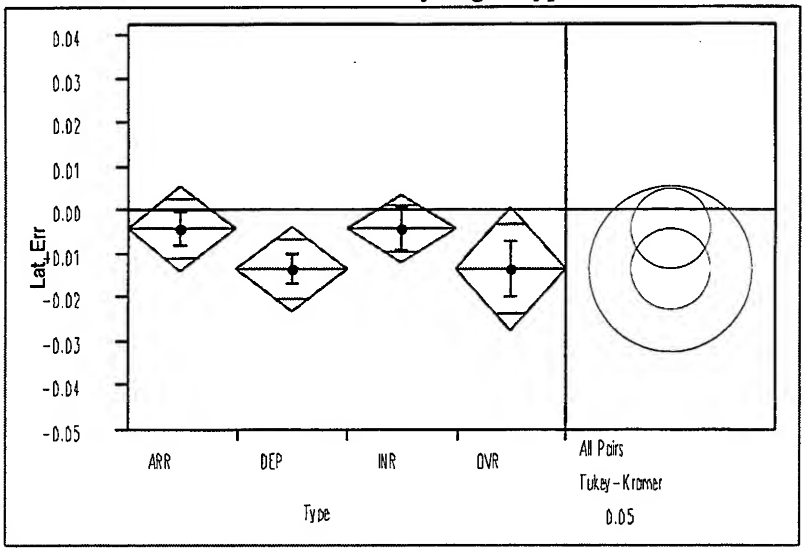
*Charts and Statistical Tests*

The statistical package used was SAS-JMP by Statistical Analysis Systems (SAS Institute, 1995).

The common graphical approach in each section was to plot the mean error by each factor. Figure A.0-2 on the following page shows a typical plot for the flight type category. The measured error in this plot is lateral error and the categories along the horizontal axis are Arrivals, Departures, Internals and Overflights. A detailed description of the chart components is provided in Section A.0.3.

Below the plot in Figure A.0-2 is numerical information provided by the JMP package including the mean and standard deviation of the error and the three statistical tests selected to analyze the data. The three tests are the Tukey-Kramer HSD (i.e. Honestly Significant Difference) Test, the Levene Test, and the Welch Test. Additional information on each test is provided in Section A.0.3.

## Lateral Error By Flight Type




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 8185 | 0.001265 | 0.395929 | 0.00438 |
| DEP | 7976 | -0.00456 | 0.346604 | 0.00388 |
| INR | 12651 | 0.004980 | 0.555031 | 0.00493 |
| OVR | 3747 | -0.00662 | 0.393963 | 0.00644 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | INR | ARR | DEP | OVR |
|---|---|---|---|---|
| INR | 0.000000 | 0.003715 | 0.009536 | 0.011603 |
| ARR | -0.00372 | 0.000000 | 0.005821 | 0.007887 |
| DEP | -0.00954 | -0.00582 | 0.000000 | 0.002067 |
| OVR | -0.0116 | -0.00789 | -0.00207 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.56916

| Abs(Dif)-LSD | INR | ARR | DEP | OVR |
|---|---|---|---|---|
| INR | -0.01468 | -0.01284 | -0.00715 | -0.01011 |
| ARR | -0.01284 | -0.01825 | -0.01254 | -0.01514 |
| DEP | -0.00715 | -0.01254 | -0.01848 | -0.02105 |
| OVR | -0.01011 | -0.01514 | -0.02105 | -0.02697 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 8185 | 0.3959291 | 0.1264577 | 0.1264098 |
| DEP | 7976 | 0.3466043 | 0.1027734 | 0.1024725 |
| INR | 12651 | 0.5550314 | 0.1533673 | 0.1527684 |
| OVR | 3747 | 0.3939632 | 0.0873013 | 0.0864671 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 3.1363 | 3 | 32555 | 0.0243 |
| Brown-Forsythe | 33.9400 | 3 | 32555 | <.0001 |
| Levene | 34.0393 | 3 | 32555 | <.0001 |
| Bartlett | 856.3893 | 3 | ? | 0.0000 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 1.1128 | 3 | 13778 | 0.3424 |

**Figure A.0-2: Example of JMP Chart for Group Comparison of the Means**

## *A.0.3 Description of JMP Charts*

Graphical analysis of the mean error for each category (i.e. look ahead time, flight type, horizontal phase of flight, and vertical phase of flight) display plots that included quantile box plots, means diamonds, error bars and comparison circles, and histograms with outlier box plots.

*Quantile Box Plot*

The quantile box plot is a "fit y by x" plot used in the analysis of horizontal, lateral, longitudinal and vertical error by look ahead time. The selected JMP plot options include display of connected means dots and quantile boxes. Figure A.0-3 is a typical plot showing horizontal error at each look ahead time. Figure A.0-4 provides a detailed description of the plot components.

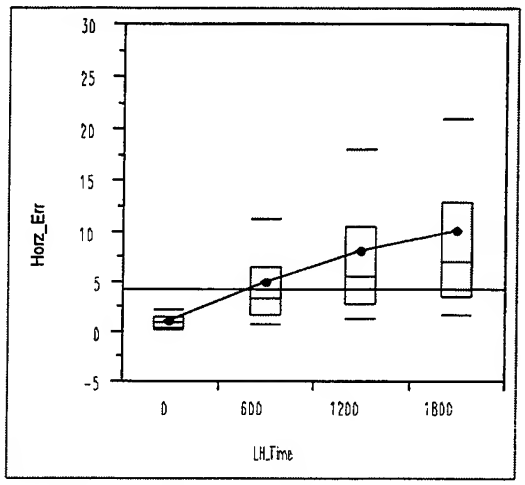



**Figure A.0-3: Connected Means and Quantile Box Plot**

Figure A.0-4 is a portion of the above plot and identifies the plot components. A horizontal line representing the grand mean for all observations, the means connected by dots, the median and various quantiles for each group are shown.

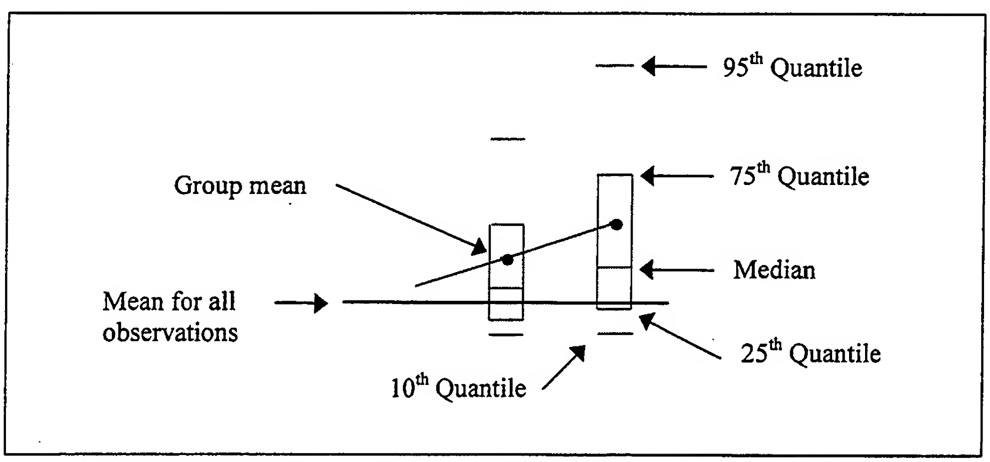



**Figure A.0-4: Components of JMP Means and Quantile Box Plot**

*Means Diamonds and T-K Comparison Circles*

Figure A.0-5 is a typical JMP plot option used to graphically present summary statistics and the Tukey-Kramer (T-K) Test. The left portion of the chart shows means diamonds, means dots with error bars. The right portion shows the T-K means comparison circles. A detailed description of the plot components is provided below.

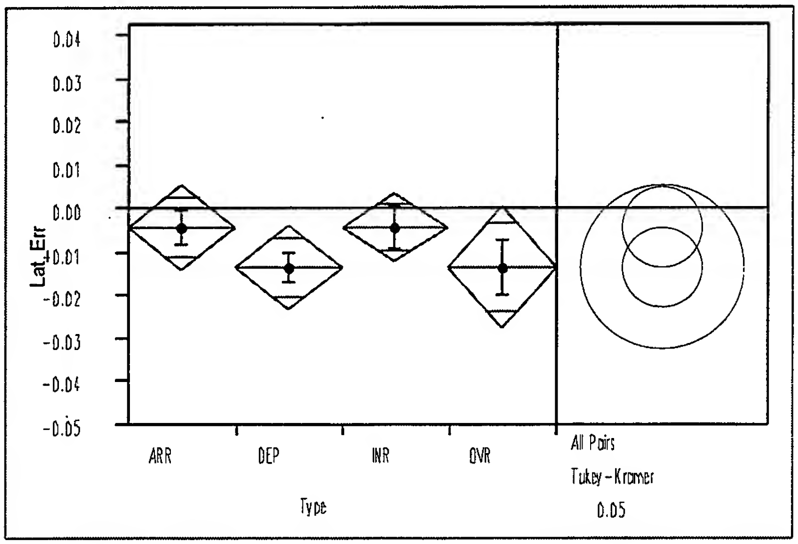



**Figure A.0-5: Means Diamonds and Tukey-Kramer Significance Test**

*Means Diamonds, Means Dots and Error Bars*

Figure A.0-6 identifies the components of the JMP mean diamond plot option. Mean diamonds are a schematic of the mean and standard error of the mean for each sample group. The green colored horizontal line across each diamond represents the group mean. The height of each diamond represents the 95% confidence interval for the group. The diamond's width for this study is equivalent for all groups for display purposes, however JMP defaults the diamond's width to be proportional to the group sample size. The blue colored dots represent the group means and the blue colored vertical bars represent one standard error ( $STD / \sqrt{n}$ ) above and below each group mean. The horizontal line crossing several diamonds represents the mean for all observations.

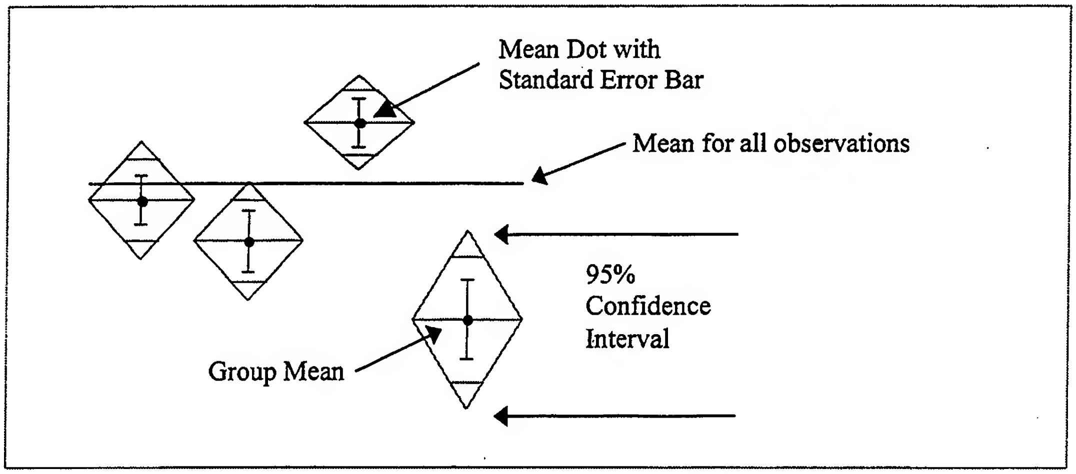



**Figure A.0-6: Components of Means Diamonds Plot Option**

*Means Comparison Circles*

JMP provides comparison circles as a graphical representation for the Tukey-Kramer Test. The comparison circle radius is calculated as follows.

$$\text{Radius} = \hat{u}_i + |\,q^*\,|\,\hat{\sigma}\sqrt{n_i^{-1}} \qquad \textbf{Equation A.0-1}$$

where,

$\hat{u}_i$ is the group mean

$q^*$ is a test value similar to the Student $t$ provided by JMP

$\hat{\sigma}$ is the group standard deviation

$n_i$ is the group sample size

By the Pythagorean theorem, a pair of means can be inferred to be significantly different if either circles do not overlap, or if they do overlap, the outer angle formed by the tangent lines through the point at which the circles intersect is greater than 90 degrees. Figure A.0-7 displays this test geometry (SAS Institute, 1995).

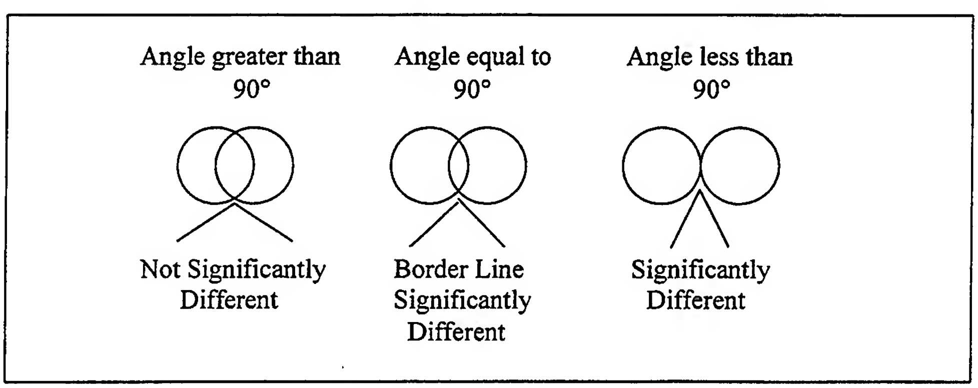



**Figure A.0-7: Geometry for JMP representation of Tukey-Kramer Comparison Circles**

Figure A.0-8 displays the connection between the mean diamonds and the comparison circles. Each diamond is represented by a circle. Each circle is vertically centered at the group mean and drawn with a radius as described above. An analysis of the circles in this example indicates that none of the factors are significantly different. This is illustrated by overlapping circles in Figure A0-8.

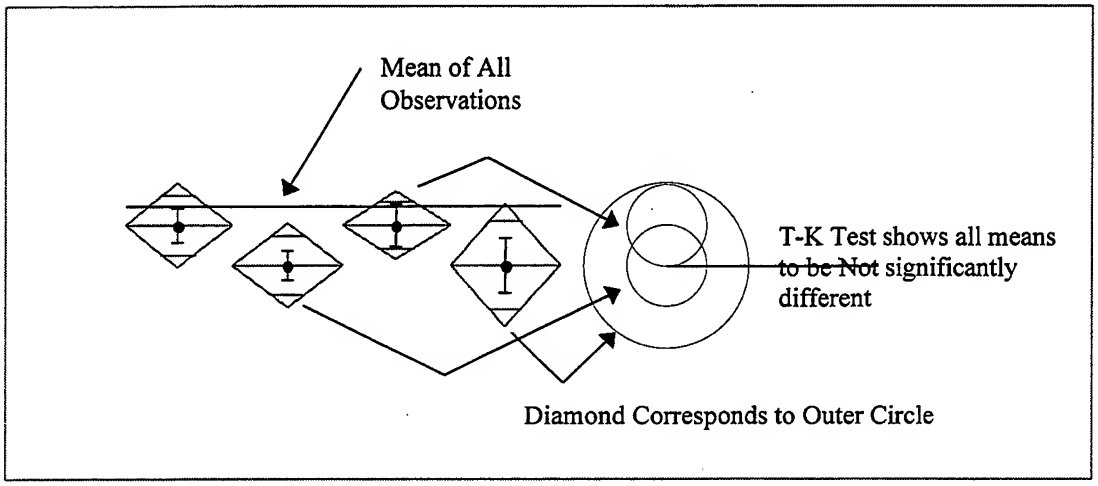



**Figure A.0-8: Connection between Means Diamonds and Comparison Circles**

*Histograms and Outlier Box Plots*

Figure A.0-9 shows a combination histogram and outlier box plot option provided by JMP. This example plot is specifically for lateral error at look ahead time zero for flights at all altitudes. Histograms were plotted for each error for each look ahead time category only.

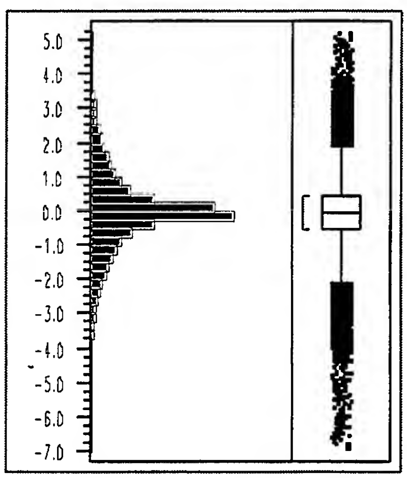



**Figure A.0-9: Histogram and Outlier Plot**

Additional description of the histogram is not required beyond indicating that the error variable for the data set is continuous and that the axis is therefore broken into intervals. The height of each bar indicates the relative frequency for the interval. Figure A.0-10 defines the components for the outlier box plot.

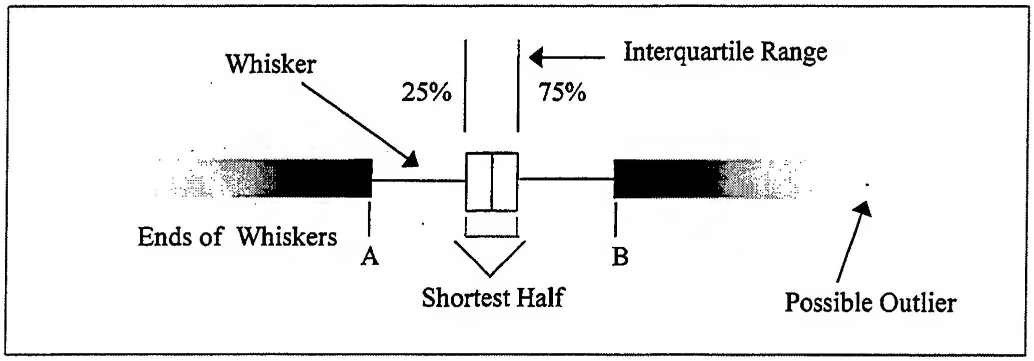



**Figure A.0-10: Outlier Box Plot**

Definitions for the components in the above Figure A.0-10 are as follows. The center box encompasses 50 percent of the sample data – the left and right ends demark the 25 percent and 75 percent quartile. The centerline of the box represents the median sample value. The ends of the whiskers (A and B) are the outer-most data points from their respective quartiles that fall within the distance computed as 1.5 times the interquartile range. The bracket along the edge of the box identifies the shortest half or the most dense 50 percent of the observations. The outlier is a possible extreme value.

### *A.0.4 Description of Statistical Tests*

The statistical tests selected from the JMP package to evaluate the error data were the Tukey-Kramer Test, the Levene Test, and the Welch Test. A brief description of each follows.

*Tukey-Kramer Test*

The Tukey-Kramer method is used to compare means having unequal sample sizes. The approximate simultaneous confidence intervals for all pairwise differences are calculated as

$$\text{Confidence Interval} = u_i - u_j \pm | q^* | \hat{\sigma} \sqrt{n_i^{-1} + n_j^{-1}} \qquad \textbf{Equation A.0-2}$$

where,

$q^*$ is the critical value such that the coverage probability equals $1-\alpha$ percent

The $q^*$ is the quantile used to scale the LSD's and has a computational role comparable to the $t$ in the Student's Distribution.

Figure A.0-11 shows the JMP format for the Tukey-Kramer Test. Positive values in any intersection indicates that pairs of means are significantly different. The $\alpha$ significance level and $q^*$ are provided. The tables values represent the actual absolute difference in the means minus the LSD, which is the

difference that would be significant. The more significantly different means are located in the northeast and southwest corners of the table (SAS Institute, 1995).

| Alpha= | 0.05 | | | |
|---|---|---|---|---|
| | Comparisons for all pairs using Tukey-Kramer HSD | | | |
| | q* = 2.56916 | | | |
| Abs(Dif)-LSD | INR | ARR | DEP | OVR |
| INR | -0.02743 | -0.00266 | 0.010011 | 0.017529 |
| ARR | -0.00266 | -0.0341 | -0.02141 | -0.01321 |
| DEP | 0.010011 | -0.02141 | -0.03455 | -0.02631 |
| OVR | 0.017529 | -0.01321 | -0.02631 | -0.0504 |

Positive values show pairs of means that are significantly different.

**Figure A.0-11: Typical JMP Table for Tukey-Kramer HSD Test**

*Levene Test*

The Levene method is a nonparametric ANOVA technique applied when the data is non-normally distributed and have unequal variances. This method is carried out on the absolute difference between observations and the group mean defined as $Z_{ij}$ rather than each observation, $y_{ij}$.

$$Z_{ij} = | y_{ij} - \bar{y}_{.j} | \quad i = 1,2,\ldots,n_j; \quad j = 1,2,\ldots,g \qquad \textbf{Equation A.0-3}$$

where,

$n$ is the number of observations within a group
$g$ is the number of group means in the comparison

The test statistic is the F-ratio with (g-1) and (n-g) degrees of freedom. The JMP test result is given as the p-value. Figure A.0-12 shows the typical results format (Neter, 1996).

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 0.5146 | 3 | 32555 | 0.6722 |
| Brown-Forsythe | 3.8946 | 3 | 32555 | 0.0086 |
| **Levene** | **5.3436** | **3** | **32555** | **0.0011** |
| Bartlett | 174.2707 | 3 | ? | <.0001 |

**Figure A.0-12: Typical JMP Table for Levene and Additional Tests**

*Welch Test*

The Welch Test is another ANOVA test for the equality of group means allowing that the group variances and sample sizes may be unequal. Figure A.0-13 shows the JMP format for the Welch Test.

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 6.4294 | 3 | 13550 | 0.0002 |

**Figure A.0-13: Typical JMP Table for Welch Test**

The typical statistical F-ratio used to test the hypothesis that the means are equal is calculated for the Welch Test as follows (Kelton and Law, 1991),

$$F = \frac{\left[\dfrac{\sum_i w_i(\bar{y}_{i.} - \tilde{y}_{..})^2}{k-1}\right]}{\left\{1 + \dfrac{2(k-2)}{k^2-1}\left[\sum_i \dfrac{\left(1-\dfrac{w_i}{u}\right)^2}{n_i - 1}\right]\right\}} \qquad \textbf{Equation A.0-4}$$

where,

$$w_i = \frac{n_i}{s_i^2}$$

$$u = \sum_i w_i$$

$$\tilde{y}_{..} = \sum \frac{w_i \bar{y}_{i.}}{u}$$

and,

$k$ is the number of sample groups

$n_i$ is the sample count of the $i$th group

$s_i^2$ is the response sample variance for the $i$th group

$\bar{y}_{i.}$ is the mean response for the $i$th group

The degrees of freedom for the test statistic numerator and denominator are calculated as follows,

DF Num $= k-1$ **Equation A.0-5**

$$\text{DF Den} = \frac{1}{\left(\frac{3}{k^2-1}\right)\left[\sum_i \frac{\left(1-\frac{w_i}{u}\right)^2}{n_i-1}\right]} \qquad \textbf{Equation A.0-6}$$

### *A.0.5 References for Appendix Introduction*


Devore, J., *Probability and Statistics for Engineering and the Sciences,* Duxbury Press, 1995.

Kelton, D., Law, A., *Simulation Modeling And Analysis*, *Second Edition*, McGraw-Hill, Incorporated, New York, 1991.

Neter, John, et Al., *Applied Linear Regression Models, Third Edition,* Irwin, 1996.

SAS Institute, *JMP Statistics and Graphics Guide, Version 3, JMP Software Package*, 1995.

## A.1 URET

### *A.1.1 Look Ahead Time*

A.1.1.1 Summary Tables

| Look Ahead Time (sec) | 0 | 300 | 600 | 900 | 1200 | 1500 | 1800 |
|---|---|---|---|---|---|---|---|
| Sample Quantity | 35928 | 29799 | 23964 | 18529 | 13836 | 9678 | 6444 |
| Avg. Horz. Error | 1.2 | 3.16 | 5.11 | 6.82 | 8.25 | 9.36 | 10.17 |
| Stddev. Horz. Error | 1.08 | 3.4 | 5.47 | 7.28 | 8.89 | 10.1 | 10.9 |
| Max. Horz. Error | 42.39 | 84.31 | 125.68 | 167.79 | 173.62 | 156.35 | 169.84 |
| Min. Horz. Error | 0 | 0.01 | 0.02 | 0.02 | 0.02 | 0.01 | 0.04 |
| Avg. Lat. Error | -0.02 | -0.1 | -0.17 | -0.21 | -0.21 | -0.24 | -0.22 |
| Stddev. Lat. Error | 1.34 | 3.64 | 5.43 | 6.98 | 8.41 | 9.49 | 10.06 |
| Max. Lat. Error | 32.23 | 65.49 | 97.45 | 129.48 | 134.87 | 120.34 | 117.09 |
| Min. Lat. Error | -16 | -39.47 | -61.74 | -94.55 | -124.94 | -143.49 | -155.99 |
| Avg. Abs. Lat. Error | 0.87 | 1.98 | 2.86 | 3.59 | 4.16 | 4.58 | 4.74 |
| Stddev. Abs. Lat. Error | 1.02 | 3.06 | 4.62 | 5.99 | 7.31 | 8.32 | 8.87 |
| Max. Abs. Lat. Error | 32.23 | 65.49 | 97.45 | 129.48 | 134.87 | 143.49 | 155.99 |
| Min. Abs. Lat. Error | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Avg. Long. Error | -0.02 | 0.09 | 0.36 | 0.52 | 0.69 | 0.79 | 0.88 |
| Stddev. Long. Error | 0.91 | 2.87 | 5.13 | 7.11 | 8.71 | 9.94 | 10.96 |
| Max. Long. Error | 11.93 | 25.52 | 91.73 | 94.25 | 96.16 | 97.63 | 98.01 |
| Min. Long. Error | -27.53 | -65.39 | -79.36 | -106.71 | -109.33 | -99.82 | -78.53 |
| Avg. Abs. Long. Error | 0.61 | 1.88 | 3.31 | 4.6 | 5.73 | 6.64 | 7.42 |
| Stddev. Abs. Long. Error | 0.67 | 2.17 | 3.94 | 5.44 | 6.59 | 7.43 | 8.12 |
| Max. Abs. Long. Error | 27.53 | 65.39 | 91.73 | 106.71 | 109.33 | 99.82 | 98.01 |
| Min. Abs. Long. Error | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Avg. Vert. Error | 49.36 | -6.95 | -126.58 | -183.49 | -200.71 | -273.61 | -327.15 |
| Stddev. Vert. Error | 662.94 | 1613.04 | 1960.92 | 2006.64 | 2113.7 | 2218.71 | 2298.25 |
| Max. Vert. Error | 36817 | 34817 | 28933 | 30746.5 | 37473.73 | 38907.87 | 31668.16 |
| Min. Vert. Error | -6824.15 | -12626.9 | -15373.8 | -16419.3 | -15900 | -17219.3 | -15800 |
| Avg. Abs. Vert. Error | 204.12 | 735.26 | 917.9 | 945.74 | 990.05 | 1065.64 | 1099.49 |
| Stddev. Abs. Vert. Error | 632.66 | 1435.73 | 1737.43 | 1779.27 | 1878.23 | 1965.15 | 2044.49 |
| Max. Abs. Vert. Error | 36817 | 34817 | 28933 | 30746.5 | 37473.73 | 38907.87 | 31668.16 |
| Min. Abs. Vert. Error | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Avg. Slant Range Error | 1.21 | 3.18 | 5.12 | 6.84 | 8.26 | 9.37 | 10.18 |
| Stddev. Slant Range Error | 1.09 | 3.39 | 5.46 | 7.27 | 8.88 | 10.09 | 10.89 |
| Max. Slant Range Error | 42.39 | 84.34 | 125.72 | 167.86 | 173.7 | 156.48 | 169.84 |
| Min. Slant Range Error | 0 | 0.01 | 0.02 | 0.03 | 0.02 | 0.01 | 0.04 |

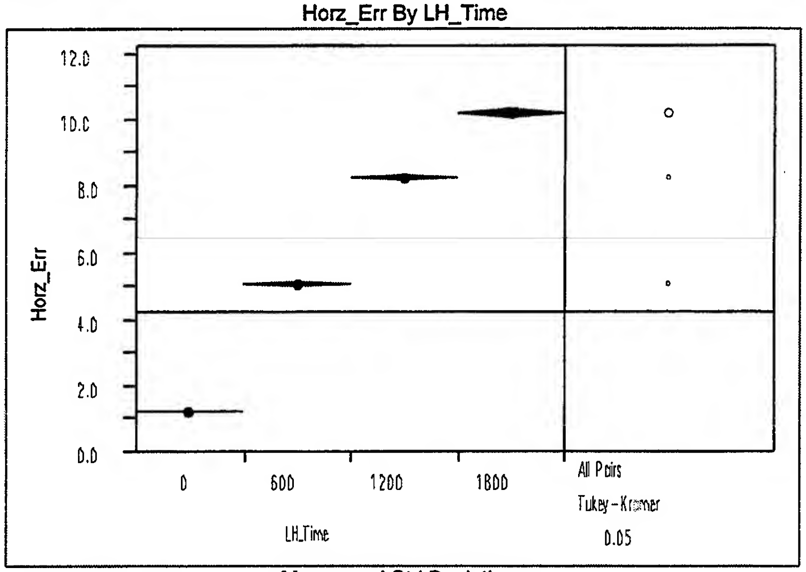
**Figure A.1- 1 Descriptive Statistics for Look Ahead Times 0 to 1800 Seconds from All Samples**

| Look Ahead Time (sec) | 0 | 300 | 600 | 900 | 1200 | 1500 | 1800 |
|---|---|---|---|---|---|---|---|
| Sample Quantity | 26148 | 22500 | 18210 | 13972 | 10374 | 7307 | 4891 |
| Avg. Horz. Error | 1.14 | 3.18 | 5.22 | 6.99 | 8.45 | 9.65 | 10.62 |
| Stddev. Horz. Error | 0.94 | 3.54 | 5.7 | 7.65 | 9.32 | 10.63 | 11.55 |
| Max. Horz. Error | 42.39 | 84.31 | 125.68 | 167.79 | 173.62 | 156.35 | 169.84 |
| Min. Horz. Error | 0 | 0.01 | 0.02 | 0.03 | 0.02 | 0.01 | 0.04 |
| Avg. Lat. Error | -0.02 | -0.12 | -0.23 | -0.28 | -0.27 | -0.38 | -0.44 |
| Stddev. Lat. Error | 1.2 | 3.8 | 5.82 | 7.58 | 9.18 | 10.25 | 10.75 |
| Max. Lat. Error | 32.23 | 65.49 | 97.45 | 129.48 | 134.87 | 120.34 | 117.09 |
| Min. Lat. Error | -6.04 | -39.47 | -61.74 | -94.55 | -124.94 | -143.49 | -155.99 |
| Avg. Abs. Lat. Error | 0.8 | 2.02 | 3.06 | 3.91 | 4.59 | 4.98 | 5.08 |
| Stddev. Abs. Lat. Error | 0.89 | 3.22 | 4.95 | 6.5 | 7.95 | 8.96 | 9.48 |
| Max. Abs. Lat. Error | 32.23 | 65.49 | 97.45 | 129.48 | 134.87 | 143.49 | 155.99 |
| Min. Abs. Lat. Error | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Avg. Long. Error | -0.02 | 0.13 | 0.4 | 0.54 | 0.8 | 0.87 | 0.78 |
| Stddev. Long. Error | 0.86 | 2.86 | 5.07 | 7.03 | 8.56 | 10.01 | 11.39 |
| Max. Long. Error | 11.93 | 25.52 | 91.73 | 94.25 | 96.16 | 97.63 | 98.01 |
| Min. Long. Error | -27.53 | -65.39 | -79.36 | -106.71 | -109.33 | -99.82 | -78.53 |
| Avg. Abs. Long. Error | 0.59 | 1.85 | 3.25 | 4.49 | 5.57 | 6.62 | 7.62 |
| Stddev. Abs. Long. Error | 0.63 | 2.19 | 3.91 | 5.44 | 6.54 | 7.55 | 8.51 |
| Max. Abs. Long. Error | 27.53 | 65.39 | 91.73 | 106.71 | 109.33 | 99.82 | 98.01 |
| Min. Abs. Long. Error | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Avg. Vert. Error | 38.78 | 59.57 | 13.09 | -42.69 | -103.07 | -169.1 | -180.17 |
| Stddev. Vert. Error | 591.85 | 1454.4 | 1819.69 | 1852.29 | 1926.2 | 2029.34 | 2142.77 |
| Max. Vert. Error | 36817 | 34817 | 28933 | 30746.5 | 37473.73 | 38907.87 | 31668.16 |
| Min. Vert. Error | -2800 | -10304.6 | -10552 | -10700 | -10485.7 | -9483.61 | -10550 |
| Avg. Abs. Vert. Error | 136.88 | 596.82 | 771.9 | 779.14 | 776.69 | 839.48 | 893.45 |
| Stddev. Abs. Vert. Error | 577.11 | 1327.64 | 1647.91 | 1680.98 | 1765.66 | 1855.27 | 1955.9 |
| Max. Abs. Vert. Error | 36817 | 34817 | 28933 | 30746.5 | 37473.73 | 38907.87 | 31668.16 |
| Min. Abs. Vert. Error | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Avg. Slant Range Error | 1.14 | 3.2 | 5.23 | 7 | 8.46 | 9.66 | 10.63 |
| Stddev. Slant Range Error | 0.94 | 3.54 | 5.7 | 7.65 | 9.31 | 10.63 | 11.54 |
| Max. Slant Range Error | 42.39 | 84.34 | 125.72 | 167.86 | 173.7 | 156.48 | 169.84 |
| Min. Slant Range Error | 0 | 0.01 | 0.02 | 0.03 | 0.02 | 0.01 | 0.04 |

**Figure A.1- 2 Descriptive Statistics for Look Ahead Times 0 to 1800 Seconds from Samples at Altitudes Above 18,000 Feet**

### A.1.1.2 Statistical Tests

Horz_Err By LH_Time




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| 0 | 35928 | 1.2048 | 1.0839 | 0.00572 |
| 600 | 23964 | 5.1080 | 5.4667 | 0.03531 |
| 1200 | 13836 | 8.2473 | 8.8872 | 0.07555 |
| 1800 | 6444 | 10.1669 | 10.8984 | 0.13576 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | 1800 | 1200 | 600 | 0 |
|---|---|---|---|---|
| 1800 | 0.00000 | 1.91965 | 5.05891 | 8.96211 |
| 1200 | -1.91965 | 0.00000 | 3.13926 | 7.04246 |
| 600 | -5.05891 | -3.13926 | 0.00000 | 3.90320 |
| 0 | -8.96211 | -7.04246 | -3.90320 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.56909

| Abs(Dif)-LSD | 1800 | 1200 | 600 | 0 |
|---|---|---|---|---|
| 1800 | -0.25856 | 1.69830 | 4.85296 | 8.76356 |
| 1200 | 1.69830 | -0.17645 | 2.98256 | 6.89562 |
| 600 | 4.85296 | 2.98256 | -0.13408 | 3.78080 |
| 0 | 8.76356 | 6.89562 | 3.78080 | -0.10950 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

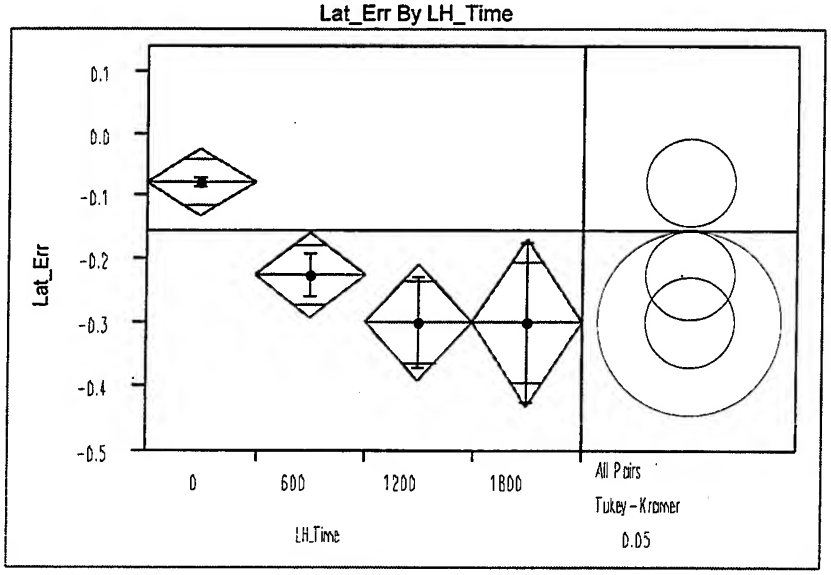
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| 0 | 35928 | 1.08390 | 0.713831 | 0.685369 |
| 600 | 23964 | 5.46669 | 3.659114 | 3.360835 |
| 1200 | 13836 | 8.88717 | 5.819963 | 5.386845 |
| 1800 | 6444 | 10.89841 | 7.014038 | 6.490122 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 438.8907 | 3 | 80168 | <.0001 |
| Brown-Forsythe | 4945.2758 | 3 | 80168 | 0.0000 |
| Levene | 7382.1189 | 3 | 80168 | 0.0000 |
| Bartlett | 33662.339 | 3 | ? | 0.0000 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 8172.2643 | 3 | 18809 | 0.0000 |

**Figure A.1- 3 Statistical Tests for Horizontal Error and Look Ahead Time for Samples at All Altitudes**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| 0 | 35928 | -0.02289 | 1.3424 | 0.00708 |
| 600 | 23964 | -0.17089 | 5.4328 | 0.03509 |
| 1200 | 13836 | -0.21287 | 8.4066 | 0.07147 |
| 1800 | 6444 | -0.22177 | 10.0570 | 0.12528 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | 0 | 600 | 1200 | 1800 |
|---|---|---|---|---|
| 0 | 0.000000 | 0.147991 | 0.189972 | 0.198874 |
| 600 | -0.14799 | 0.000000 | 0.041980 | 0.050883 |
| 1200 | -0.18997 | -0.04198 | 0.000000 | 0.008903 |
| 1800 | -0.19887 | -0.05088 | -0.0089 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.56909

| Abs(Dif)-LSD | 0 | 600 | 1200 | 1800 |
|---|---|---|---|---|
| 0 | -0.10491 | 0.030718 | 0.049287 | 0.008655 |
| 600 | 0.030718 | -0.12845 | -0.10815 | -0.14643 |
| 1200 | 0.049287 | -0.10815 | -0.16905 | -0.20316 |
| 1800 | 0.008655 | -0.14643 | -0.20316 | -0.24771 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| 0 | 35928 | 1.34238 | 0.871379 | 0.871062 |
| 600 | 23964 | 5.43278 | 2.881018 | 2.864207 |
| 1200 | 13836 | 8.40656 | 4.184118 | 4.157163 |
| 1800 | 6444 | 10.05703 | 4.775601 | 4.743031 |

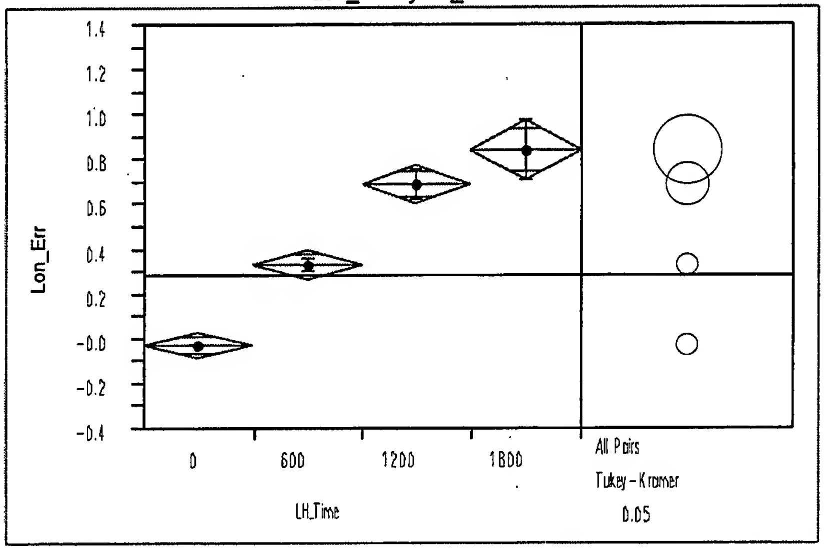
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 447.7444 | 3 | 80168 | <.0001 |
| Brown-Forsythe | 2485.9252 | 3 | 80168 | 0.0000 |
| Levene | 2539.9707 | 3 | 80168 | 0.0000 |
| Bartlett | 27206.524 | 3 | ? | 0.0000 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 8.6634 | 3 | 18950 | <.0001 |

**Figure A.1- 4 Statistical Tests for Lateral Error and Look Ahead Time for Samples at All Altitudes**

Lon_Err By LH_Time




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| 0 | 35928 | -0.01595 | 0.9075 | 0.00479 |
| 600 | 23964 | 0.361484 | 5.1286 | 0.03313 |
| 1200 | 13836 | 0.694580 | 8.7067 | 0.07402 |
| 1800 | 6444 | 0.875566 | 10.9635 | 0.13657 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | 1800 | 1200 | 600 | 0 |
|---|---|---|---|---|
| 1800 | 0.000000 | 0.180986 | 0.514082 | 0.891517 |
| 1200 | -0.18099 | 0.000000 | 0.333096 | 0.710531 |
| 600 | -0.51408 | -0.3331 | 0.000000 | 0.377436 |
| 0 | -0.89152 | -0.71053 | -0.37744 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.56909

| Abs(Dif)-LSD | 1800 | 1200 | 600 | 0 |
|---|---|---|---|---|
| 1800 | -0.25189 | -0.03465 | 0.313445 | 0.698090 |
| 1200 | -0.03465 | -0.1719 | 0.180432 | 0.567474 |
| 600 | 0.313445 | 0.180432 | -0.13062 | 0.258185 |
| 0 | 0.698090 | 0.567474 | 0.258185 | -0.10668 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| 0 | 35928 | 0.90754 | 0.608203 | 0.608152 |
| 600 | 23964 | 5.12860 | 3.300234 | 3.299056 |
| 1200 | 13836 | 8.70666 | 5.696847 | 5.696779 |
| 1800 | 6444 | 10.96346 | 7.376215 | 7.376185 |

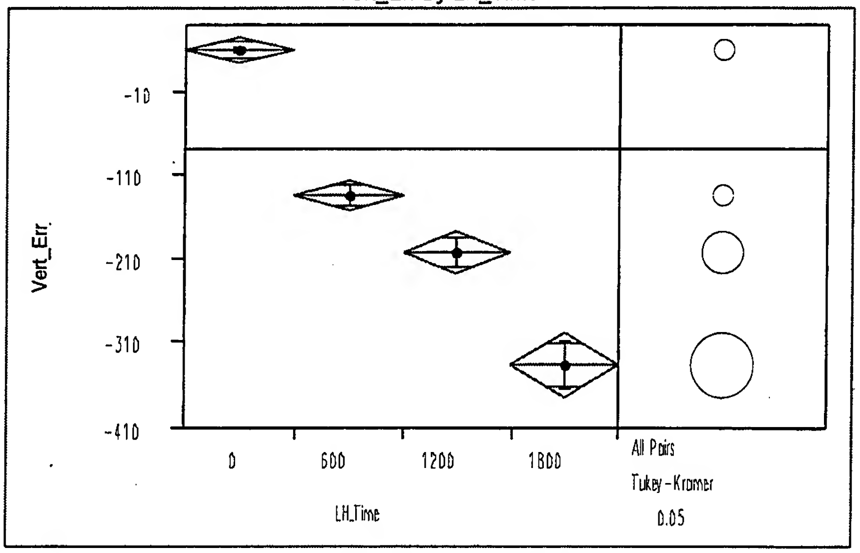
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 1089.3936 | 3 | 80168 | 0.0000 |
| Brown-Forsythe | 8142.8187 | 3 | 80168 | 0.0000 |
| Levene | 8145.8936 | 3 | 80168 | 0.0000 |
| Bartlett | 37702.337 | 3 | ? | 0.0000 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 86.1528 | 3 | 18755 | <.0001 |

**Figure A.1- 5 Statistical Tests for Longitudinal Error and Look Ahead Time for Samples at All Altitudes**

Vert_Err By LH_Time




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| 0 | 35928 | 49.356 | 662.94 | 3.497 |
| 600 | 23964 | -126.578 | 1960.92 | 12.667 |
| 1200 | 13836 | -200.706 | 2113.70 | 17.970 |
| 1800 | 6444 | -327.149 | 2298.25 | 28.630 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | 0 | 600 | 1200 | 1800 |
|---|---|---|---|---|
| 0 | 0.000 | 175.935 | 250.062 | 376.506 |
| 600 | -175.935 | 0.000 | 74.128 | 200.571 |
| 1200 | -250.062 | -74.128 | 0.000 | 126.443 |
| 1800 | -376.506 | -200.571 | -126.443 | 0.000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.56909

| Abs(Dif)-LSD | 0 | 600 | 1200 | 1800 |
|---|---|---|---|---|
| 0 | -30.560 | 141.773 | 209.081 | 321.094 |
| 600 | 141.773 | -37.419 | 30.394 | 143.095 |
| 1200 | 209.081 | 30.394 | -49.245 | 64.669 |
| 1800 | 321.094 | 143.095 | 64.669 | -72.159 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

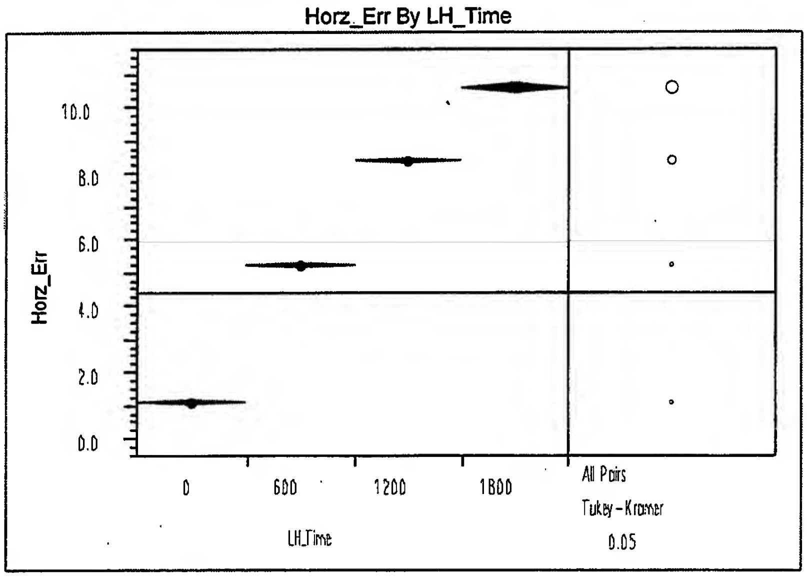
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| 0 | 35928 | 662.937 | 228.883 | 204.125 |
| 600 | 23964 | 1960.920 | 980.693 | 917.897 |
| 1200 | 13836 | 2113.700 | 1091.512 | 990.048 |
| 1800 | 6444 | 2298.255 | 1262.250 | 1099.493 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 346.4660 | 3 | 80168 | <.0001 |
| Brown-Forsythe | 1926.9792 | 3 | 80168 | 0.0000 |
| Levene | 2460.3926 | 3 | 80168 | 0.0000 |
| Bartlett | 13539.252 | 3 | ? | 0.0000 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 166.8785 | 3 | 19585 | <.0001 |

**Figure A.1- 6 Statistical Tests for Vertical Error and Look Ahead Time for Samples at All Altitudes**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| 0 | 26148 | 1.1369 | 0.9427 | 0.00583 |
| 600 | 18210 | 5.2202 | 5.7019 | 0.04225 |
| 1200 | 10374 | 8.4471 | 9.3181 | 0.09149 |
| 1800 | 4891 | 10.6181 | 11.5491 | 0.16514 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | 1800 | 1200 | 600 | 0 |
|---|---|---|---|---|
| 1800 | 0.00000 | 2.17100 | 5.39794 | 9.48126 |
| 1200 | -2.17100 | 0.00000 | 3.22694 | 7.31026 |
| 600 | -5.39794 | -3.22694 | 0.00000 | 4.08332 |
| 0 | -9.48126 | -7.31026 | -4.08332 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.56910

| Abs(Dif)-LSD | 1800 | 1200 | 600 | 0 |
|---|---|---|---|---|
| 1800 | -0.31329 | 1.90228 | 5.14843 | 9.23990 |
| 1200 | 1.90228 | -0.21512 | 3.03637 | 7.13049 |
| 600 | 5.14843 | 3.03637 | -0.16236 | 3.93378 |
| 0 | 9.23990 | 7.13049 | 3.93378 | -0.13550 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| 0 | 26148 | 0.94270 | 0.651186 | 0.630549 |
| 600 | 18210 | 5.70192 | 3.823976 | 3.488516 |
| 1200 | 10374 | 9.31807 | 6.029985 | 5.557946 |
| 1800 | 4891 | 11.54910 | 7.371841 | 6.820868 |

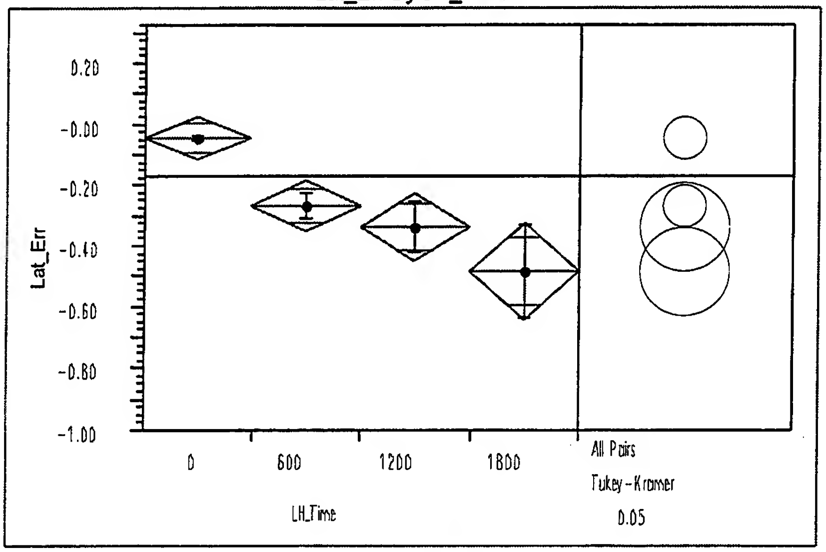
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 320.4503 | 3 | 59619 | <.0001 |
| Brown-Forsythe | 3634.9075 | 3 | 59619 | 0.0000 |
| Levene | 5489.3036 | 3 | 59619 | 0.0000 |
| Bartlett | 27901.034 | 3 | ? | 0.0000 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 6203.3622 | 3 | 14182 | 0.0000 |

**Figure A.1- 7 Statistical Tests for Horizontal Error and Look Ahead Time for Samples at Altitudes Above 18,000 Feet**

Lat_Err By LH_Time




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| 0 | 26148 | -0.02491 | 1.1993 | 0.00742 |
| 600 | 18210 | -0.23282 | 5.8169 | 0.04311 |
| 1200 | 10374 | -0.26522 | 9.1795 | 0.09012 |
| 1800 | 4891 | -0.44387 | 10.7500 | 0.15371 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | 0 | 600 | 1200 | 1800 |
|---|---|---|---|---|
| 0 | 0.000000 | 0.207907 | 0.240304 | 0.418956 |
| 600 | -0.20791 | 0.000000 | 0.032397 | 0.211049 |
| 1200 | -0.2403 | -0.0324 | 0.000000 | 0.178652 |
| 1800 | -0.41896 | -0.21105 | -0.17865 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.56910

| Abs(Dif)-LSD | 0 | 600 | 1200 | 1800 |
|---|---|---|---|---|
| 0 | -0.13312 | 0.060990 | 0.063682 | 0.181820 |
| 600 | 0.060990 | -0.15952 | -0.15484 | -0.0341 |
| 1200 | 0.063682 | -0.15484 | -0.21135 | -0.08537 |
| 1800 | 0.181820 | -0.0341 | -0.08537 | -0.30781 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

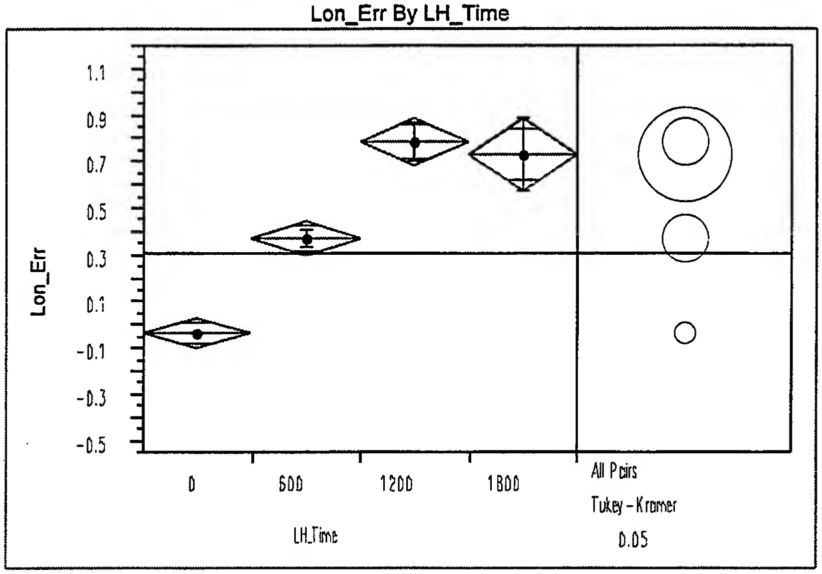
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| 0 | 26148 | 1.19928 | 0.803931 | 0.803539 |
| 600 | 18210 | 5.81685 | 3.088452 | 3.058630 |
| 1200 | 10374 | 9.17947 | 4.634173 | 4.594108 |
| 1800 | 4891 | 10.75002 | 5.179103 | 5.080457 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 356.9652 | 3 | 59619 | <.0001 |
| Brown-Forsythe | 2021.3661 | 3 | 59619 | 0.0000 |
| Levene | 2102.8972 | 3 | 59619 | 0.0000 |
| Bartlett | 23098.169 | 3 | ? | 0.0000 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 12.1520 | 3 | 14260 | <.0001 |

**Figure A.1- 8 Statistical Tests for Lateral Error and Look Ahead Time for Samples at Altitudes Above 18,000 Feet**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| 0 | 26148 | -0.02453 | 0.8612 | 0.00533 |
| 600 | 18210 | 0.399772 | 5.0709 | 0.03758 |
| 1200 | 10374 | 0.798268 | 8.5567 | 0.08401 |
| 1800 | 4891 | 0.776635 | 11.3924 | 0.16290 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | 1200 | 1800 | 600 | 0 |
|---|---|---|---|---|
| 1200 | 0.000000 | 0.021634 | 0.398496 | 0.822802 |
| 1800 | -0.02163 | 0.000000 | 0.376863 | 0.801168 |
| 600 | -0.3985 | -0.37686 | 0.000000 | 0.424306 |
| 0 | -0.8228 | -0.80117 | -0.42431 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.56910

| Abs(Dif)-LSD | 1200 | 1800 | 600 | 0 |
|---|---|---|---|---|
| 1200 | -0.20041 | -0.22872 | 0.220953 | 0.655324 |
| 1800 | -0.22872 | -0.29187 | 0.144411 | 0.576311 |
| 600 | 0.220953 | 0.144411 | -0.15126 | 0.284995 |
| 0 | 0.655324 | 0.576311 | 0.284995 | -0.12623 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

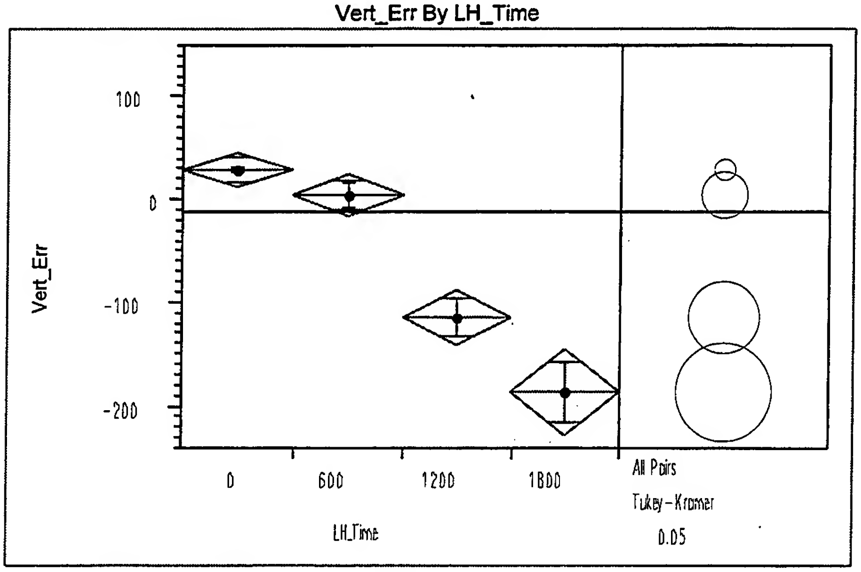
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| 0 | 26148 | 0.86125 | 0.591115 | 0.591057 |
| 600 | 18210 | 5.07091 | 3.245947 | 3.242524 |
| 1200 | 10374 | 8.55670 | 5.551472 | 5.547547 |
| 1800 | 4891 | 11.39239 | 7.592835 | 7.592169 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 753.7629 | 3 | 59619 | 0.0000 |
| Brown-Forsythe | 5913.6135 | 3 | 59619 | 0.0000 |
| Levene | 5930.1703 | 3 | 59619 | 0.0000 |
| Bartlett | 28718.836 | 3 | ? | 0.0000 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 80.6834 | 3 | 14183 | <.0001 |

**Figure A.1- 9 Statistical Tests for Longitudinal Error and Look Ahead Time for Samples at Altitudes Above 18,000 Feet**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| 0 | 26148 | 38.780 | 591.85 | 3.660 |
| 600 | 18210 | 13.094 | 1819.69 | 13.485 |
| 1200 | 10374 | -103.070 | 1926.20 | 18.912 |
| 1800 | 4891 | -180.173 | 2142.77 | 30.639 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | 0 | 600 | 1200 | 1800 |
|---|---|---|---|---|
| 0 | 0.000 | 25.686 | 141.850 | 218.952 |
| 600 | -25.686 | 0.000 | 116.164 | 193.266 |
| 1200 | -141.850 | -116.164 | 0.000 | 77.103 |
| 1800 | -218.952 | -193.266 | -77.103 | 0.000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.56910

| Abs(Dif)-LSD | 0 | 600 | 1200 | 1800 |
|---|---|---|---|---|
| 0 | -33.229 | -10.986 | 97.764 | 159.762 |
| 600 | -10.986 | -39.818 | 69.428 | 132.077 |
| 1200 | 97.764 | 69.428 | -52.754 | 11.202 |
| 1800 | 159.762 | 132.077 | 11.202 | -76.830 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| 0 | 26148 | 591.852 | 160.7907 | 136.8790 |
| 600 | 18210 | 1819.695 | 780.0067 | 771.9043 |
| 1200 | 10374 | 1926.200 | 835.6573 | 776.6929 |
| 1800 | 4891 | 2142.772 | 998.2717 | 893.4473 |

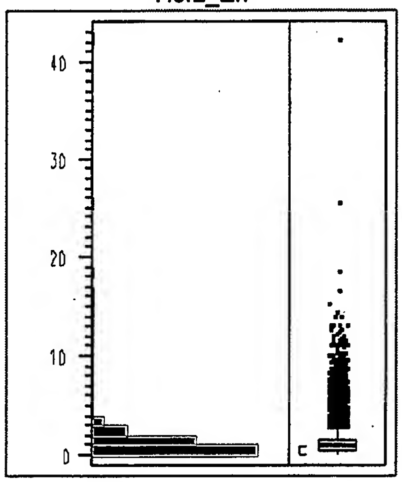
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 160.9942 | 3 | 59619 | <.0001 |
| Brown-Forsythe | 1154.5767 | 3 | 59619 | 0.0000 |
| Levene | 1257.8525 | 3 | 59619 | 0.0000 |
| Bartlett | 10409.214 | 3 | ? | 0.0000 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 34.6228 | 3 | 14798 | <.0001 |

**Figure A.1- 10 Statistical Tests for Vertical Error and Look Ahead Time for Samples at Altitudes Above 18,000 Feet**

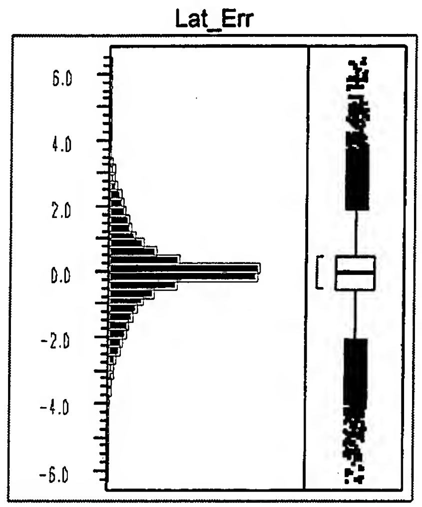
### A.1.1.3 Histograms




| | Quantiles | |
|---|---|---|
| maximum | 100.0% | 42.390 |
| | 99.5% | 6.717 |
| | 97.5% | 3.499 |
| | 90.0% | 2.374 |
| quartile | 75.0% | 1.585 |
| median | 50.0% | 0.961 |
| quartile | 25.0% | 0.528 |
| | 10.0% | 0.258 |
| | 2.5% | 0.101 |
| | 0.5% | 0.032 |
| minimum | 0.0% | 0.000 |

| Moments | |
|---|---|
| Mean | 1.20 |
| Std Dev | 1.08 |
| Std Error Mean | 0.01 |
| Upper 95% Mean | 1.22 |
| Lower 95% Mean | 1.19 |
| N | 35928.00 |
| Sum Weights | 35928.00 |

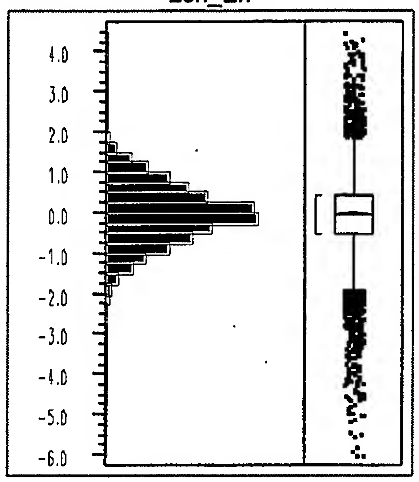
**Figure A.1- 11 Histogram and Quantiles for Horizontal Error and Look Ahead Time 0 for Samples at All Altitudes**




| | Quantiles | |
|---|---|---|
| maximum | 100.0% | 32.233 |
| | 99.5% | 3.838 |
| | 97.5% | 2.725 |
| | 90.0% | 1.493 |
| quartile | 75.0% | 0.483 |
| median | 50.0% | -0.003 |
| quartile | 25.0% | -0.531 |
| | 10.0% | -1.571 |
| | 2.5% | -2.761 |
| | 0.5% | -3.915 |
| minimum | 0.0% | -15.999 |

| Moments | |
|---|---|
| Mean | -0.02 |
| Std Dev | 1.34 |
| Std Error Mean | 0.01 |
| Upper 95% Mean | -0.01 |
| Lower 95% Mean | -0.04 |
| N | 35928.00 |
| Sum Weights | 35928.00 |

**Figure A.1- 12 Histogram and Quantiles for Lateral Error and Look Ahead Time 0 for Samples at All Altitudes**



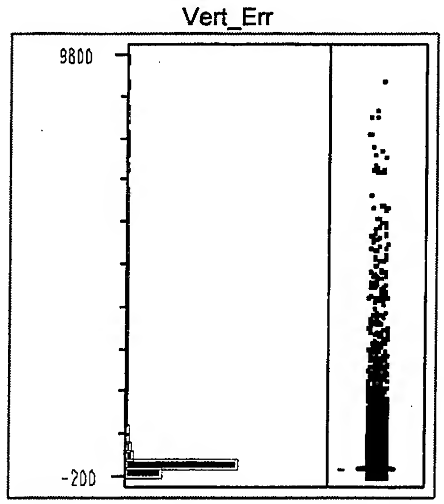

Quantiles

| | | |
|---|---|---|
| maximum | 100.0% | 11.926 |
| | 99.5% | 2.393 |
| | 97.5% | 1.461 |
| | 90.0% | 0.948 |
| quartile | 75.0% | 0.466 |
| median | 50.0% | -0.008 |
| quartile | 25.0% | -0.488 |
| | 10.0% | -0.970 |
| | 2.5% | -1.520 |
| | 0.5% | -2.549 |
| minimum | 0.0% | -27.532 |

Moments

| | |
|---|---|
| Mean | -0.02 |
| Std Dev | 0.91 |
| Std Error Mean | 0.00 |
| Upper 95% Mean | -0.01 |
| Lower 95% Mean | -0.03 |
| N | 35928.00 |
| Sum Weights | 35928.00 |

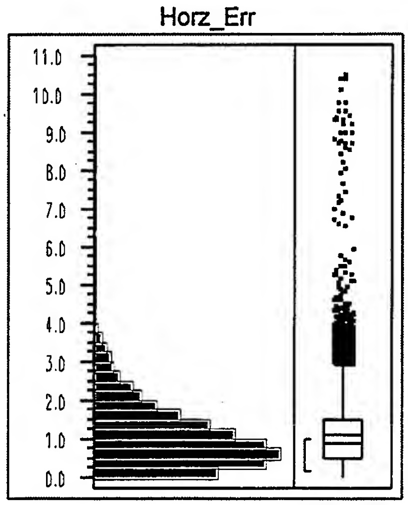
**Figure A.1- 13 Histogram and Quantiles for Longitudinal Error and Look Ahead Time 0 for Samples at All Altitudes**




| | Quantiles | |
|---|---|---|
| maximum | 100.0% | 36817 |
| | 99.5% | 2831 |
| | 97.5% | 1077 |
| | 90.0% | 344 |
| quartile | 75.0% | 24 |
| median | 50.0% | 0 |
| quartile | 25.0% | 0 |
| | 10.0% | -200 |
| | 2.5% | -832 |
| | 0.5% | -1513 |
| minimum | 0.0% | -6824 |

| Moments | |
|---|---|
| Mean | 49.36 |
| Std Dev | 662.94 |
| Std Error Mean | 3.50 |
| Upper 95% Mean | 56.21 |
| Lower 95% Mean | 42.50 |
| N | 35928.00 |
| Sum Weights | 35928.00 |

**Figure A.1- 14 Histogram and Quantiles for Vertical Error and Look Ahead Time 0 for Samples at All Altitudes**



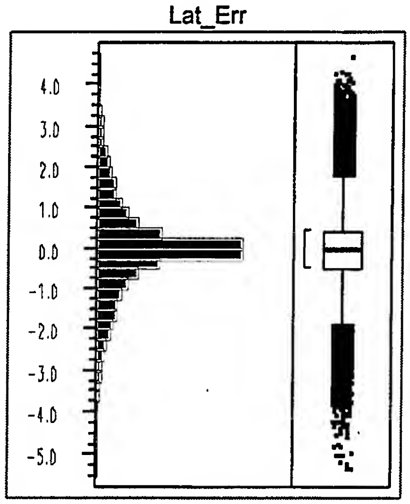

Quantiles

| | | |
|---|---|---|
| maximum | 100.0% | 42.390 |
| | 99.5% | 4.092 |
| | 97.5% | 3.242 |
| | 90.0% | 2.266 |
| quartile | 75.0% | 1.528 |
| median | 50.0% | 0.938 |
| quartile | 25.0% | 0.516 |
| | 10.0% | 0.251 |
| | 2.5% | 0.097 |
| | 0.5% | 0.031 |
| minimum | 0.0% | 0.000 |

Moments

| | |
|---|---|
| Mean | 1.14 |
| Std Dev | 0.94 |
| Std Error Mean | 0.01 |
| Upper 95% Mean | 1.15 |
| Lower 95% Mean | 1.13 |
| N | 26148.00 |
| Sum Weights | 26148.00 |

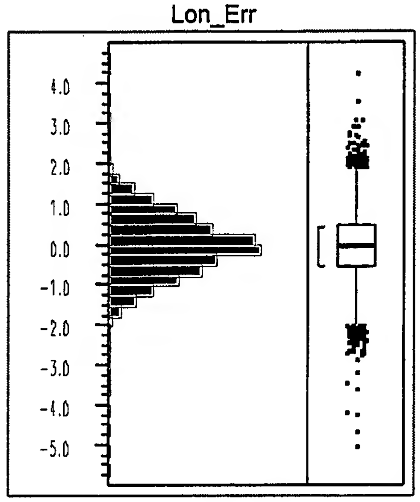
**Figure A.1- 15 Histogram and Quantiles for Horizontal Error and Look Ahead Time 0 for Samples at Altitudes Above 18,000 Feet**




| | Quantiles | |
|---|---|---|
| maximum | 100.0% | 32.233 |
| | 99.5% | 3.470 |
| | 97.5% | 2.578 |
| | 90.0% | 1.403 |
| quartile | 75.0% | 0.432 |
| median | 50.0% | -0.004 |
| quartile | 25.0% | -0.491 |
| | 10.0% | -1.515 |
| | 2.5% | -2.646 |
| | 0.5% | -3.547 |
| minimum | 0.0% | -6.035 |

| Moments | |
|---|---|
| Mean | -0.02 |
| Std Dev | 1.20 |
| Std Error Mean | 0.01 |
| Upper 95% Mean | -0.01 |
| Lower 95% Mean | -0.04 |
| N | 26148.00 |
| Sum Weights | 26148.00 |

**Figure A.1- 16 Histogram and Quantiles for Lateral Error and Look Ahead Time 0 for Samples at Altitudes Above 18,000 Feet**




Quantiles

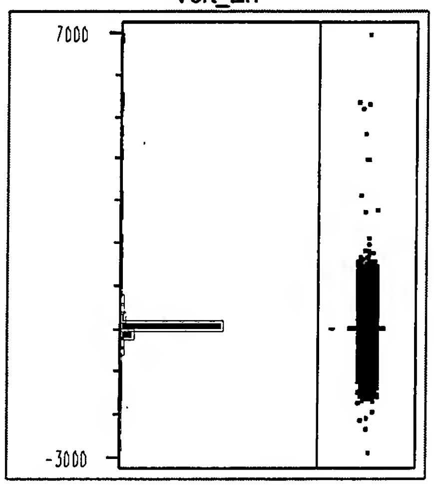
| | | |
|---|---|---|
| maximum | 100.0% | 11.926 |
| | 99.5% | 1.824 |
| | 97.5% | 1.401 |
| | 90.0% | 0.931 |
| quartile | 75.0% | 0.468 |
| median | 50.0% | -0.016 |
| quartile | 25.0% | -0.510 |
| | 10.0% | -0.966 |
| | 2.5% | -1.451 |
| | 0.5% | -1.938 |
| minimum | 0.0% | -27.532 |

Moments

| | |
|---|---|
| Mean | -0.02 |
| Std Dev | 0.86 |
| Std Error Mean | 0.01 |
| Upper 95% Mean | -0.01 |
| Lower 95% Mean | -0.03 |
| N | 26148.00 |
| Sum Weights | 26148.00 |

**Figure A.1- 17 Histogram and Quantiles for Longitudinal Error and Look Ahead Time 0 for Samples at Altitudes Above 18,000 Feet**

Vert_Err



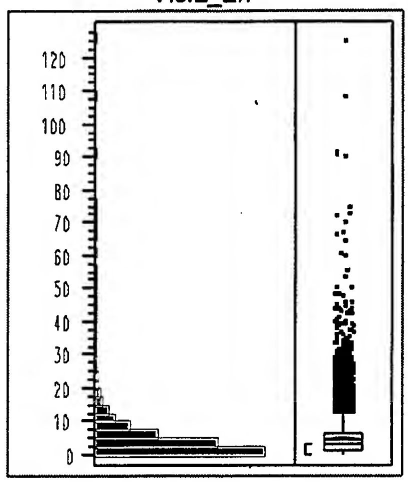

Quantiles

| | | |
|---|---|---|
| maximum | 100.0% | 36817 |
| | 99.5% | 1315 |
| | 97.5% | 889 |
| | 90.0% | 200 |
| quartile | 75.0% | 0 |
| median | 50.0% | 0 |
| quartile | 25.0% | 0 |
| | 10.0% | -100 |
| | 2.5% | -607 |
| | 0.5% | -1101 |
| minimum | 0.0% | -2800 |

Moments

| | |
|---|---|
| Mean | 38.78 |
| Std Dev | 591.85 |
| Std Error Mean | 3.66 |
| Upper 95% Mean | 45.95 |
| Lower 95% Mean | 31.61 |
| N | 26148.00 |
| Sum Weights | 26148.00 |

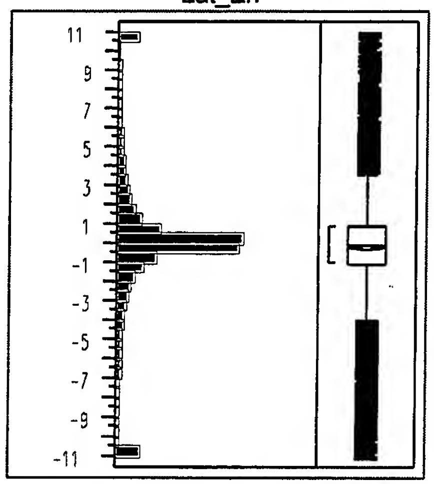
**Figure A.1- 18 Histogram and Quantiles for Vertical Error and Look Ahead Time 0 for Samples at Altitudes Above 18,000 Feet**




| | Quantiles | |
|---|---|---|
| maximum | 100.0% | 125.68 |
| | 99.5% | 29.29 |
| | 97.5% | 19.31 |
| | 90.0% | 11.40 |
| quartile | 75.0% | 6.61 |
| median | 50.0% | 3.41 |
| quartile | 25.0% | 1.73 |
| | 10.0% | 0.84 |
| | 2.5% | 0.34 |
| | 0.5% | 0.14 |
| minimum | 0.0% | 0.02 |

| Moments | |
|---|---|
| Mean | 5.11 |
| Std Dev | 5.47 |
| Std Error Mean | 0.04 |
| Upper 95% Mean | 5.18 |
| Lower 95% Mean | 5.04 |
| N | 23964.00 |
| Sum Weights | 23964.00 |

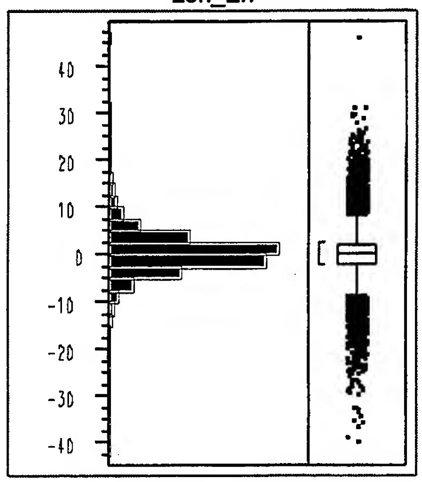
**Figure A.1- 19 Histogram and Quantiles for Horizontal Error and Look Ahead Time 600 for Samples at All Altitudes**




| | Quantiles | |
|---|---|---|
| maximum | 100.0% | 97.448 |
| | 99.5% | 20.990 |
| | 97.5% | 11.379 |
| | 90.0% | 4.208 |
| quartile | 75.0% | 0.891 |
| median | 50.0% | -0.002 |
| quartile | 25.0% | -1.028 |
| | 10.0% | -5.083 |
| | 2.5% | -12.677 |
| | 0.5% | -21.637 |
| minimum | 0.0% | -61.740 |

| Moments | |
|---|---|
| Mean | -0.17 |
| Std Dev | 5.43 |
| Std Error Mean | 0.04 |
| Upper 95% Mean | -0.10 |
| Lower 95% Mean | -0.24 |
| N | 23964.00 |
| Sum Weights | 23964.00 |

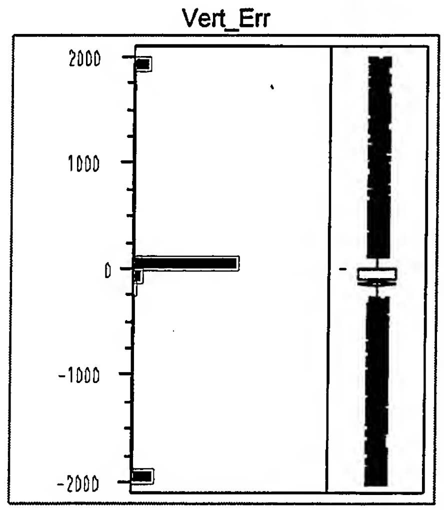
**Figure A.1- 20 Histogram and Quantiles for Lateral Error and Look Ahead Time 600 for Samples at All Altitudes**




| | Quantiles | |
|---|---|---|
| maximum | 100.0% | 91.729 |
| | 99.5% | 18.430 |
| | 97.5% | 11.242 |
| | 90.0% | 5.349 |
| quartile | 75.0% | 2.459 |
| median | 50.0% | 0.264 |
| quartile | 25.0% | -1.891 |
| | 10.0% | -4.385 |
| | 2.5% | -9.435 |
| | 0.5% | -17.924 |
| minimum | 0.0% | -79.363 |

| Moments | |
|---|---|
| Mean | 0.36 |
| Std Dev | 5.13 |
| Std Error Mean | 0.03 |
| Upper 95% Mean | 0.43 |
| Lower 95% Mean | 0.30 |
| N | 23964.00 |
| Sum Weights | 23964.00 |

**Figure A.1- 21 Histogram and Quantiles for Longitudinal Error and Look Ahead Time 600 for Samples at All Altitudes**



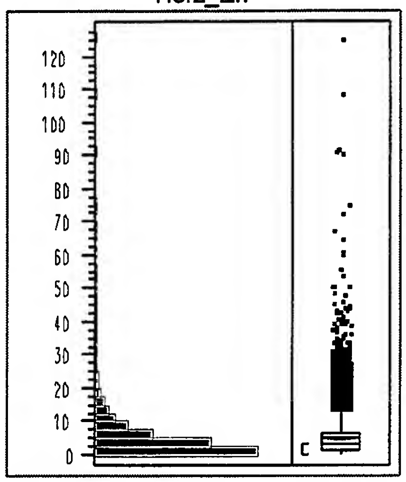

Quantiles

| | | |
|---|---|---|
| maximum | 100.0% | 28933 |
| | 99.5% | 8000 |
| | 97.5% | 4300 |
| | 90.0% | 1273 |
| quartile | 75.0% | 0 |
| median | 50.0% | 0 |
| quartile | 25.0% | -100 |
| | 10.0% | -2000 |
| | 2.5% | -4549 |
| | 0.5% | -7304 |
| minimum | 0.0% | -15374 |

Moments

| | |
|---|---|
| Mean | -126.58 |
| Std Dev | 1960.92 |
| Std Error Mean | 12.67 |
| Upper 95% Mean | -101.75 |
| Lower 95% Mean | -151.41 |
| N | 23964.00 |
| Sum Weights | 23964.00 |

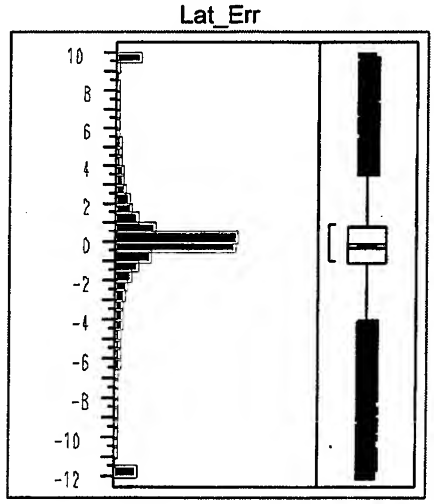
**Figure A.1- 22 Histogram and Quantiles for Vertical Error and Look Ahead Time 600 for Samples at All Altitudes**




| | Quantiles | |
|---|---|---|
| maximum | 100.0% | 125.68 |
| | 99.5% | 30.02 |
| | 97.5% | 20.02 |
| | 90.0% | 11.96 |
| quartile | 75.0% | 6.74 |
| median | 50.0% | 3.39 |
| quartile | 25.0% | 1.71 |
| | 10.0% | 0.84 |
| | 2.5% | 0.33 |
| | 0.5% | 0.13 |
| minimum | 0.0% | 0.02 |

| Moments | |
|---|---|
| Mean | 5.22 |
| Std Dev | 5.70 |
| Std Error Mean | 0.04 |
| Upper 95% Mean | 5.30 |
| Lower 95% Mean | 5.14 |
| N | 18210.00 |
| Sum Weights | 18210.00 |

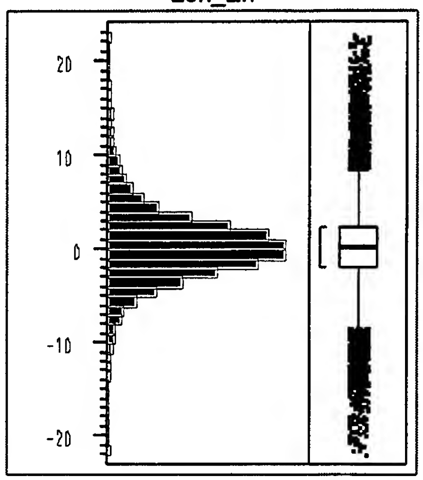
**Figure A.1- 23 Histogram and Quantiles for Horizontal Error and Look Ahead Time 600 for Samples at Altitudes Above 18,000 Feet**




| | Quantiles | |
|---|---|---|
| maximum | 100.0% | 97.448 |
| | 99.5% | 21.986 |
| | 97.5% | 12.112 |
| | 90.0% | 4.455 |
| quartile | 75.0% | 0.863 |
| median | 50.0% | -0.010 |
| quartile | 25.0% | -1.064 |
| | 10.0% | -5.616 |
| | 2.5% | -13.873 |
| | 0.5% | -22.433 |
| minimum | 0.0% | -61.740 |

| Moments | |
|---|---|
| Mean | -0.23 |
| Std Dev | 5.82 |
| Std Error Mean | 0.04 |
| Upper 95% Mean | -0.15 |
| Lower 95% Mean | -0.32 |
| N | 18210.00 |
| Sum Weights | 18210.00 |

**Figure A.1- 24 Histogram and Quantiles for Lateral Error and Look Ahead Time 600 for Samples at Altitudes Above 18,000 Feet**

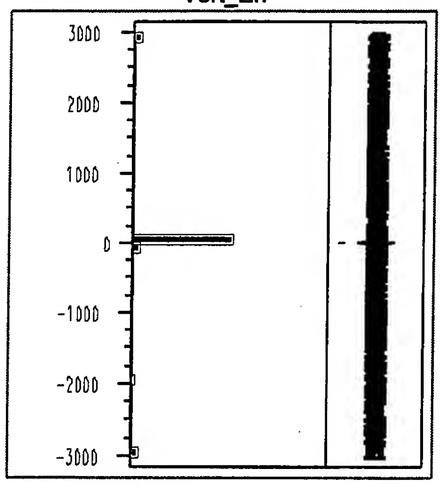



| | Quantiles | |
|---|---|---|
| maximum | 100.0% | 91.729 |
| | 99.5% | 18.705 |
| | 97.5% | 11.698 |
| | 90.0% | 5.270 |
| quartile | 75.0% | 2.406 |
| median | 50.0% | 0.233 |
| quartile | 25.0% | -1.847 |
| | 10.0% | -4.153 |
| | 2.5% | -9.090 |
| | 0.5% | -17.506 |
| minimum | 0.0% | -79.363 |

| Moments | |
|---|---|
| Mean | 0.40 |
| Std Dev | 5.07 |
| Std Error Mean | 0.04 |
| Upper 95% Mean | 0.47 |
| Lower 95% Mean | 0.33 |
| N | 18210.00 |
| Sum Weights | 18210.00 |

**Figure A.1- 25 Histogram and Quantiles for Longitudinal Error and Look Ahead Time 600 for Samples at Altitudes Above 18,000 Feet**

Vert_Err



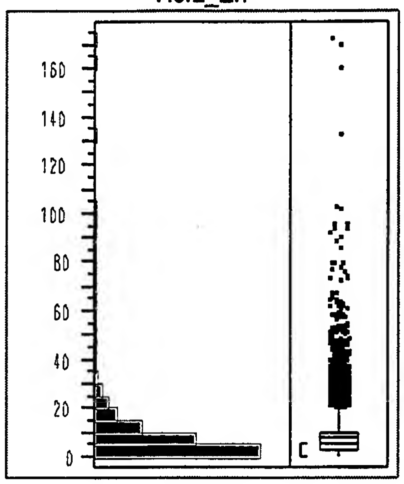

Quantiles

| | | |
|---|---|---|
| maximum | 100.0% | 28933 |
| | 99.5% | 8533 |
| | 97.5% | 4420 |
| | 90.0% | 1144 |
| quartile | 75.0% | 0 |
| median | 50.0% | 0 |
| quartile | 25.0% | 0 |
| | 10.0% | -1563 |
| | 2.5% | -4000 |
| | 0.5% | -6032 |
| minimum | 0.0% | -10552 |

Moments

| | |
|---|---|
| Mean | 13.09 |
| Std Dev | 1819.69 |
| Std Error Mean | 13.48 |
| Upper 95% Mean | 39.53 |
| Lower 95% Mean | -13.34 |
| N | 18210.00 |
| Sum Weights | 18210.00 |

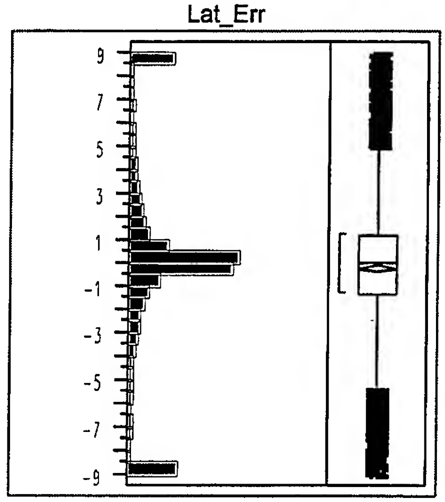
**Figure A.1- 26 Histogram and Quantiles for Vertical Error and Look Ahead Time 600 for Samples at Altitudes Above 18,000 Feet**




| | Quantiles | |
|---|---|---|
| maximum | 100.0% | 173.62 |
| | 99.5% | 51.34 |
| | 97.5% | 30.25 |
| | 90.0% | 18.15 |
| quartile | 75.0% | 10.56 |
| median | 50.0% | 5.64 |
| quartile | 25.0% | 2.85 |
| | 10.0% | 1.34 |
| | 2.5% | 0.52 |
| | 0.5% | 0.22 |
| minimum | 0.0% | 0.02 |

| Moments | |
|---|---|
| Mean | 8.25 |
| Std Dev | 8.89 |
| Std Error Mean | 0.08 |
| Upper 95% Mean | 8.40 |
| Lower 95% Mean | 8.10 |
| N | 13836.00 |
| Sum Weights | 13836.00 |

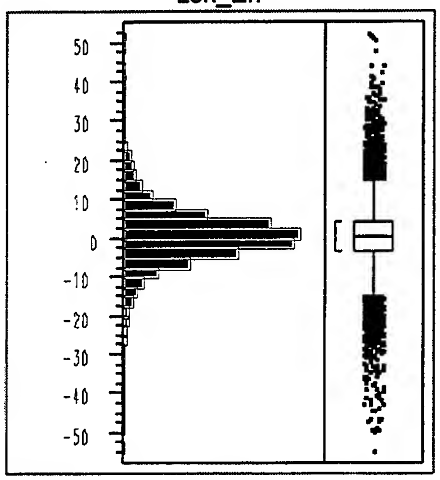
**Figure A.1- 27 Histogram and Quantiles for Horizontal Error and Look Ahead Time 1200 for Samples at All Altitudes**




| | Quantiles | |
|---|---|---|
| maximum | 100.0% | 134.87 |
| | 99.5% | 30.74 |
| | 97.5% | 16.67 |
| | 90.0% | 6.21 |
| quartile | 75.0% | 1.21 |
| median | 50.0% | 0.01 |
| quartile | 25.0% | -1.36 |
| | 10.0% | -7.04 |
| | 2.5% | -18.78 |
| | 0.5% | -36.18 |
| minimum | 0.0% | -124.94 |

| Moments | |
|---|---|
| Mean | -0.21 |
| Std Dev | 8.41 |
| Std Error Mean | 0.07 |
| Upper 95% Mean | -0.07 |
| Lower 95% Mean | -0.35 |
| N | 13836.00 |
| Sum Weights | 13836.00 |

**Figure A.1- 28 Histogram and Quantiles for Lateral Error and Look Ahead Time 1200 for Samples at All Altitudes**



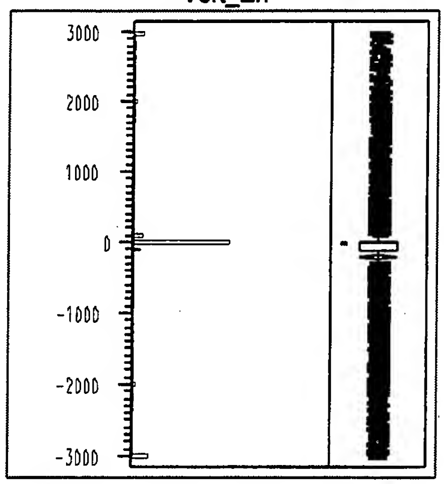

Quantiles

| | | |
|---|---|---|
| maximum | 100.0% | 96.16 |
| | 99.5% | 29.86 |
| | 97.5% | 18.53 |
| | 90.0% | 9.34 |
| quartile | 75.0% | 4.50 |
| median | 50.0% | 0.66 |
| quartile | 25.0% | -3.13 |
| | 10.0% | -7.55 |
| | 2.5% | -16.60 |
| | 0.5% | -30.62 |
| minimum | 0.0% | -109.33 |

Moments

| | |
|---|---|
| Mean | 0.69 |
| Std Dev | 8.71 |
| Std Error Mean | 0.07 |
| Upper 95% Mean | 0.84 |
| Lower 95% Mean | 0.55 |
| N | 13836.00 |
| Sum Weights | 13836.00 |

**Figure A.1- 29 Histogram and Quantiles for Longitudinal Error and Look Ahead Time 1200 for Samples at All Altitudes**



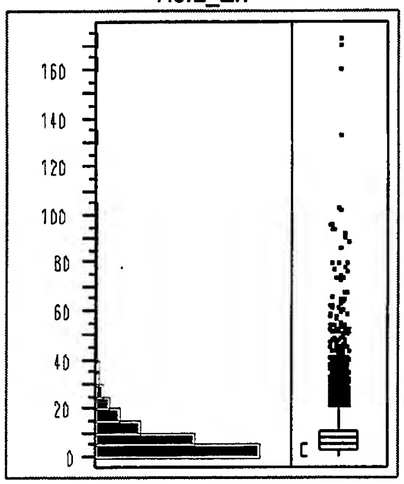

Quantiles

| | | |
|---|---|---|
| maximum | 100.0% | 37474 |
| | 99.5% | 7774 |
| | 97.5% | 4033 |
| | 90.0% | 1235 |
| quartile | 75.0% | 0 |
| median | 50.0% | 0 |
| quartile | 25.0% | -100 |
| | 10.0% | -2459 |
| | 2.5% | -4933 |
| | 0.5% | -7560 |
| minimum | 0.0% | -15900 |

Moments

| | |
|---|---|
| Mean | -200.71 |
| Std Dev | 2113.70 |
| Std Error Mean | 17.97 |
| Upper 95% Mean | -165.48 |
| Lower 95% Mean | -235.93 |
| N | 13836.00 |
| Sum Weights | 13836.00 |

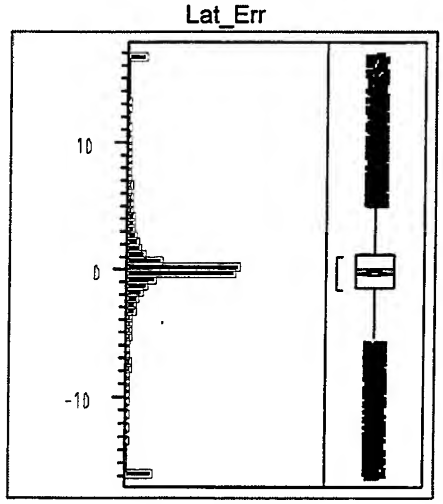
**Figure A.1- 30 Histogram and Quantiles for Vertical Error and Look Ahead Time 1200 for Samples at All Altitudes**




| | Quantiles | |
|---|---|---|
| maximum | 100.0% | 173.62 |
| | 99.5% | 53.61 |
| | 97.5% | 31.39 |
| | 90.0% | 18.72 |
| quartile | 75.0% | 10.80 |
| median | 50.0% | 5.69 |
| quartile | 25.0% | 2.90 |
| | 10.0% | 1.35 |
| | 2.5% | 0.50 |
| | 0.5% | 0.21 |
| minimum | 0.0% | 0.02 |

| Moments | |
|---|---|
| Mean | 8.45 |
| Std Dev | 9.32 |
| Std Error Mean | 0.09 |
| Upper 95% Mean | 8.63 |
| Lower 95% Mean | 8.27 |
| N | 10374.00 |
| Sum Weights | 10374.00 |

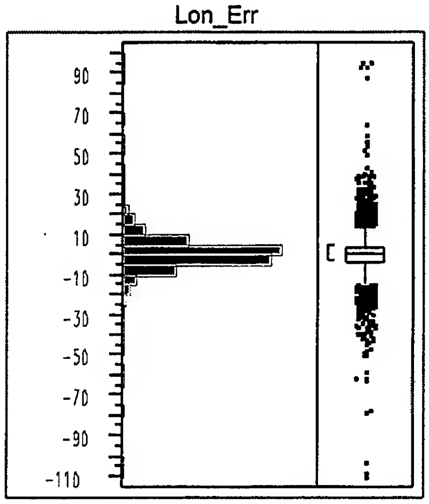
**Figure A.1- 31 Histogram and Quantiles for Horizontal Error and Look Ahead Time 1200 for Samples at Altitudes Above 18,000 Feet**




| | Quantiles | |
|---|---|---|
| maximum | 100.0% | 134.87 |
| | 99.5% | 33.48 |
| | 97.5% | 18.17 |
| | 90.0% | 7.16 |
| quartile | 75.0% | 1.25 |
| median | 50.0% | 0.01 |
| quartile | 25.0% | -1.44 |
| | 10.0% | -8.13 |
| | 2.5% | -20.01 |
| | 0.5% | -39.32 |
| minimum | 0.0% | -124.94 |

| Moments | |
|---|---|
| Mean | -0.27 |
| Std Dev | 9.18 |
| Std Error Mean | 0.09 |
| Upper 95% Mean | -0.09 |
| Lower 95% Mean | -0.44 |
| N | 10374.00 |
| Sum Weights | 10374.00 |

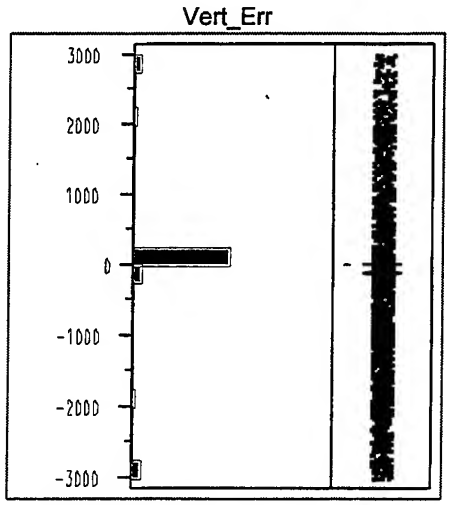
**Figure A.1- 32 Histogram and Quantiles for Lateral Error and Look Ahead Time 1200 for Samples at Altitudes Above 18,000 Feet**




| | Quantiles | |
|---|---|---|
| maximum | 100.0% | 96.16 |
| | 99.5% | 30.18 |
| | 97.5% | 18.87 |
| | 90.0% | 9.22 |
| quartile | 75.0% | 4.39 |
| median | 50.0% | 0.57 |
| quartile | 25.0% | -3.14 |
| | 10.0% | -7.08 |
| | 2.5% | -15.20 |
| | 0.5% | -29.10 |
| minimum | 0.0% | -109.33 |

| Moments | |
|---|---|
| Mean | 0.80 |
| Std Dev | 8.56 |
| Std Error Mean | 0.08 |
| Upper 95% Mean | 0.96 |
| Lower 95% Mean | 0.63 |
| N | 10374.00 |
| Sum Weights | 10374.00 |

**Figure A.1- 33 Histogram and Quantiles for Longitudinal Error and Look Ahead Time 1200 for Samples at Altitudes Above 18,000 Feet**



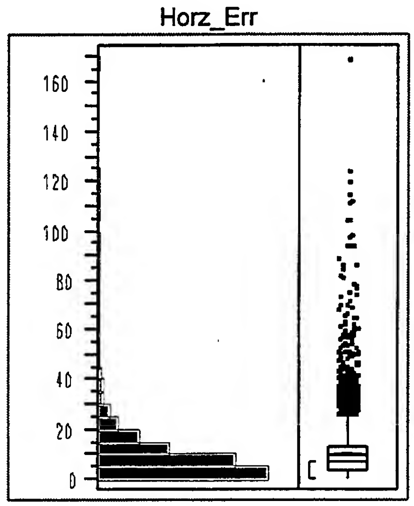

Quantiles

| | | |
|---|---|---|
| maximum | 100.0% | 37474 |
| | 99.5% | 8000 |
| | 97.5% | 4000 |
| | 90.0% | 551 |
| quartile | 75.0% | 0 |
| median | 50.0% | 0 |
| quartile | 25.0% | 0 |
| | 10.0% | -2000 |
| | 2.5% | -4000 |
| | 0.5% | -6815 |
| minimum | 0.0% | -10486 |

Moments

| | |
|---|---|
| Mean | -103.07 |
| Std Dev | 1926.20 |
| Std Error Mean | 18.91 |
| Upper 95% Mean | -66.00 |
| Lower 95% Mean | -140.14 |
| N | 10374.00 |
| Sum Weights | 10374.00 |

**Figure A.1- 34 Histogram and Quantiles for Vertical Error and Look Ahead Time 1200 for Samples at Altitudes Above 18,000 Feet**

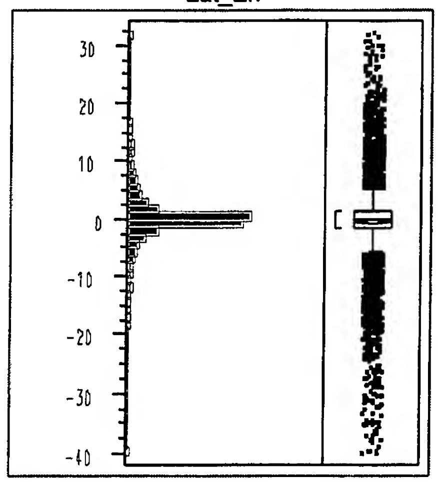



| | Quantiles | |
|---|---|---|
| maximum | 100.0% | 169.84 |
| | 99.5% | 66.98 |
| | 97.5% | 38.45 |
| | 90.0% | 21.14 |
| quartile | 75.0% | 13.00 |
| median | 50.0% | 7.08 |
| quartile | 25.0% | 3.64 |
| | 10.0% | 1.78 |
| | 2.5% | 0.72 |
| | 0.5% | 0.33 |
| minimum | 0.0% | 0.04 |

| Moments | |
|---|---|
| Mean | 10.167 |
| Std Dev | 10.898 |
| Std Error Mean | 0.136 |
| Upper 95% Mean | 10.433 |
| Lower 95% Mean | 9.901 |
| N | 6444.000 |
| Sum Weights | 6444.000 |

**Figure A.1- 35 Histogram and Quantiles for Horizontal Error and Look Ahead Time 1800 for Samples at All Altitudes**

Lat_Err



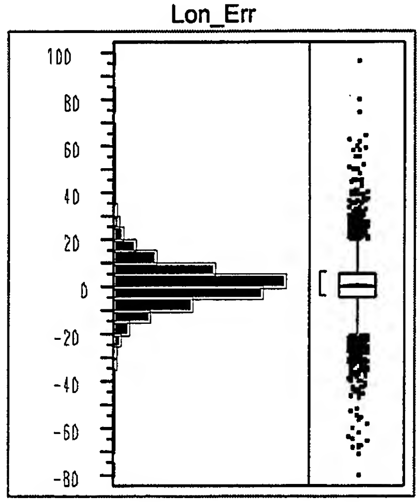

Quantiles

| | | |
|---|---|---|
| maximum | 100.0% | 117.09 |
| | 99.5% | 36.81 |
| | 97.5% | 17.96 |
| | 90.0% | 7.08 |
| quartile | 75.0% | 1.52 |
| median | 50.0% | 0.03 |
| quartile | 25.0% | -1.31 |
| | 10.0% | -7.32 |
| | 2.5% | -20.59 |
| | 0.5% | -45.73 |
| minimum | 0.0% | -155.99 |

Moments

| | |
|---|---|
| Mean | -0.222 |
| Std Dev | 10.057 |
| Std Error Mean | 0.125 |
| Upper 95% Mean | 0.024 |
| Lower 95% Mean | -0.467 |
| N | 6444.000 |
| Sum Weights | 6444.000 |

**Figure A.1- 36 Histogram and Quantiles for Lateral Error and Look Ahead Time 1800 for Samples at All Altitudes**



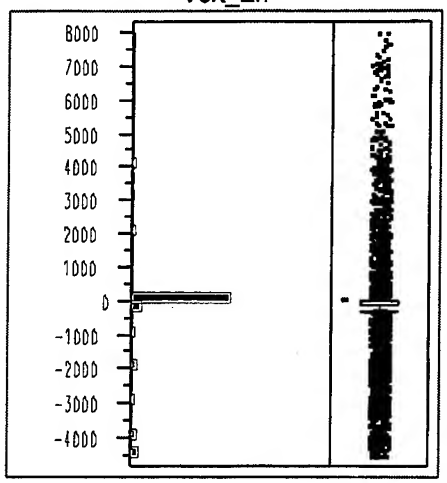

Quantiles

| | | |
|---|---|---|
| maximum | 100.0% | 98.009 |
| | 99.5% | 41.024 |
| | 97.5% | 23.072 |
| | 90.0% | 12.060 |
| quartile | 75.0% | 5.899 |
| median | 50.0% | 0.904 |
| quartile | 25.0% | -4.277 |
| | 10.0% | -10.251 |
| | 2.5% | -20.647 |
| | 0.5% | -39.811 |
| minimum | 0.0% | -78.525 |

Moments

| | |
|---|---|
| Mean | 0.876 |
| Std Dev | 10.963 |
| Std Error Mean | 0.137 |
| Upper 95% Mean | 1.143 |
| Lower 95% Mean | 0.608 |
| N | 6444.000 |
| Sum Weights | 6444.000 |

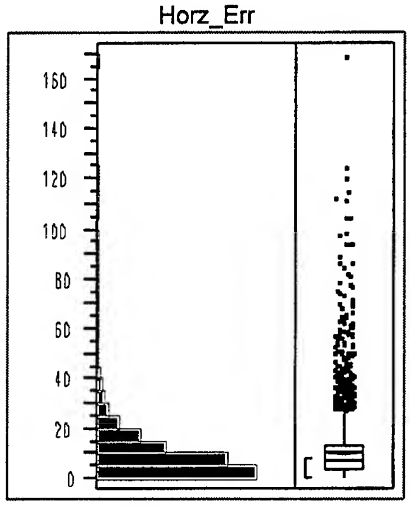
**Figure A.1- 37 Histogram and Quantiles for Longitudinal Error and Look Ahead Time 1800 for Samples at All Altitudes**




| | Quantiles | |
|---|---|---|
| maximum | 100.0% | 31668 |
| | 99.5% | 7732 |
| | 97.5% | 4000 |
| | 90.0% | 1100 |
| quartile | 75.0% | 0 |
| median | 50.0% | 0 |
| quartile | 25.0% | -100 |
| | 10.0% | -3100 |
| | 2.5% | -5699 |
| | 0.5% | -8000 |
| minimum | 0.0% | -15800 |

| Moments | |
|---|---|
| Mean | -327.149 |
| Std Dev | 2298.255 |
| Std Error Mean | 28.630 |
| Upper 95% Mean | -271.024 |
| Lower 95% Mean | -383.275 |
| N | 6444.000 |
| Sum Weights | 6444.000 |

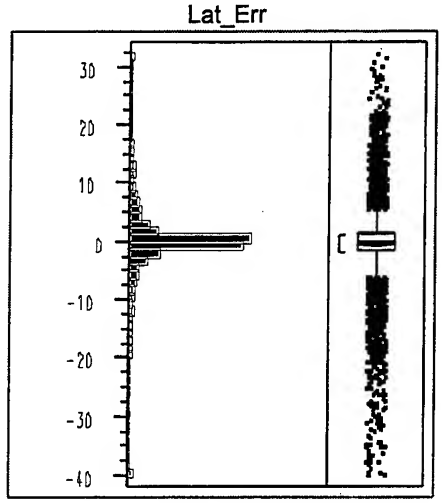
**Figure A.1- 38 Histogram and Quantiles for Vertical Error and Look Ahead Time 1800 for Samples at All Altitudes**




| | Quantiles | |
|---|---|---|
| maximum | 100.0% | 169.84 |
| | 99.5% | 74.93 |
| | 97.5% | 39.65 |
| | 90.0% | 21.87 |
| quartile | 75.0% | 13.58 |
| median | 50.0% | 7.32 |
| quartile | 25.0% | 3.75 |
| | 10.0% | 1.87 |
| | 2.5% | 0.74 |
| | 0.5% | 0.35 |
| minimum | 0.0% | 0.04 |

| Moments | |
|---|---|
| Mean | 10.618 |
| Std Dev | 11.549 |
| Std Error Mean | 0.165 |
| Upper 95% Mean | 10.942 |
| Lower 95% Mean | 10.294 |
| N | 4891.000 |
| Sum Weights | 4891.000 |

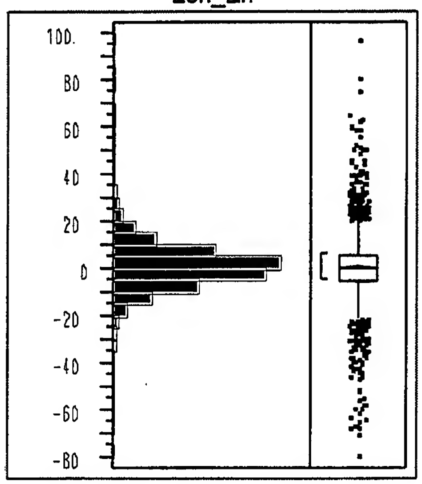
**Figure A.1- 39 Histogram and Quantiles for Horizontal Error and Look Ahead Time 1800 for Samples at Altitudes Above 18,000 Feet**




| | Quantiles | |
|---|---|---|
| maximum | 100.0% | 117.09 |
| | 99.5% | 35.76 |
| | 97.5% | 18.17 |
| | 90.0% | 7.52 |
| quartile | 75.0% | 1.51 |
| median | 50.0% | 0.02 |
| quartile | 25.0% | -1.44 |
| | 10.0% | -8.47 |
| | 2.5% | -23.14 |
| | 0.5% | -51.61 |
| minimum | 0.0% | -155.99 |

| Moments | |
|---|---|
| Mean | -0.444 |
| Std Dev | 10.750 |
| Std. Error Mean | 0.154 |
| Upper 95% Mean | -0.143 |
| Lower 95% Mean | -0.745 |
| N | 4891.000 |
| Sum Weights | 4891.000 |

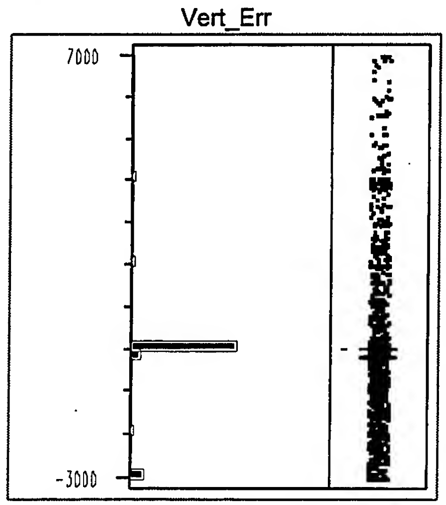
**Figure A.1- 40 Histogram and Quantiles for Lateral Error and Look Ahead Time 1800 for Samples at Altitudes Above 18,000 Feet**




| | Quantiles | |
|---|---|---|
| maximum | 100.0% | 98.009 |
| | 99.5% | 43.388 |
| | 97.5% | 24.060 |
| | 90.0% | 12.093 |
| quartile | 75.0% | 5.896 |
| median | 50.0% | 0.674 |
| quartile | 25.0% | -4.559 |
| | 10.0% | -10.386 |
| | 2.5% | -21.096 |
| | 0.5% | -42.616 |
| minimum | 0.0% | -78.525 |

| Moments | |
|---|---|
| Mean | 0.777 |
| Std Dev | 11.392 |
| Std Error Mean | 0.163 |
| Upper 95% Mean | 1.096 |
| Lower 95% Mean | 0.457 |
| N | 4891.000 |
| Sum Weights | 4891.000 |

**Figure A.1- 41 Histogram and Quantiles for Longitudinal Error and Look Ahead Time 1800 for Samples at Altitudes Above 18,000 Feet**




| Quantiles | | |
|---|---|---|
| maximum | 100.0% | 31668 |
| | 99.5% | 7405 |
| | 97.5% | 4000 |
| | 90.0% | 493 |
| quartile | 75.0% | 0 |
| median | 50.0% | 0 |
| quartile | 25.0% | 0 |
| | 10.0% | -2450 |
| | 2.5% | -4757 |
| | 0.5% | -7115 |
| minimum | 0.0% | -10550 |

| Moments | |
|---|---|
| Mean | -180.173 |
| Std Dev | 2142.772 |
| Std Error Mean | 30.639 |
| Upper 95% Mean | -120.105 |
| Lower 95% Mean | -240.240 |
| N | 4891.000 |
| Sum Weights | 4891.000 |

**Figure A.1- 42 Histogram and Quantiles for Vertical Error and Look Ahead Time 1800 for Samples at Altitudes Above 18,000 Feet**

## *A.1.2 Flight Type Per Look Ahead Time*

### A.1.2.1 Summary Tables

| LOOKAHEAD TIME | | | 0 Seconds | |
|---|---|---|---|---|
| Flight type | OVR | ARR | DEP | INR |
| Sample Quantity | 19015 | 8448 | 7726 | 739 |
| Avg. Horz. Error | 1.15 | 1.31 | 1.22 | 1.39 |
| Stddev. Horz. Error | 0.96 | 1.4 | 0.91 | 1.4 |
| Max. Horz. Error | 42.39 | 16.91 | 11.93 | 12.94 |
| Min. Horz. Error | 0 | 0 | 0 | 0 |
| Avg. Lat. Error | -0.04 | 0.03 | -0.07 | 0.17 |
| Stddev. Lat. Error | 1.22 | 1.61 | 1.25 | 1.76 |
| Max. Lat. Error | 32.23 | 13.48 | 5.21 | 11.15 |
| Min. Lat. Error | -6.04 | -16 | -5.18 | -12.62 |
| Avg. Abs. Lat. Error | 0.81 | 0.94 | 0.92 | 1.13 |
| Stddev. Abs. Lat. Error | 0.91 | 1.31 | 0.85 | 1.37 |
| Max. Abs. Lat. Error | 32.23 | 16 | 5.21 | 12.62 |
| Min. Abs. Lat. Error | 0 | 0 | 0 | 0 |
| Avg. Long. Error | -0.03 | -0.06 | 0.06 | 0 |
| Stddev. Long. Error | 0.87 | 1.03 | 0.86 | 0.87 |
| Max. Long. Error | 9.46 | 9.33 | 11.93 | 4.1 |
| Min. Long. Error | -27.53 | -9.81 | -11.19 | -4.93 |
| Avg. Abs. Long. Error | 0.59 | 0.67 | 0.58 | 0.58 |
| Stddev. Abs. Long. Error | 0.63 | 0.78 | 0.64 | 0.65 |
| Max. Abs. Long. Error | 27.53 | 9.81 | 11.93 | 4.93 |
| Min. Abs. Long. Error | 0 | 0 | 0 | 0 |
| Avg. Vert. Error | 32.35 | 70.19 | 61.55 | 121.23 |
| Stddev. Vert. Error | 499.73 | 925.09 | 660.83 | 758.4 |
| Max. Vert. Error | 26434.39 | 36817 | 28933 | 5907.7 |
| Min. Vert. Error | -2264.79 | -6824.15 | -3113.24 | -4200 |
| Avg. Abs. Vert. Error | 100.61 | 373.89 | 261.37 | 328.34 |
| Stddev. Abs. Vert. Error | 490.57 | 849.06 | 610.05 | 694.21 |
| Max. Abs. Vert. Error | 26434.39 | 36817 | 28933 | 5907.7 |
| Min. Abs. Vert. Error | 0 | 0 | 0 | 0 |
| Avg. Slant Range Error | 1.15 | 1.31 | 1.22 | 1.4 |
| Stddev. Slant Range Error | 0.96 | 1.4 | 0.91 | 1.4 |
| Max. Slant Range Error | 42.39 | 16.91 | 11.93 | 12.96 |
| Min. Slant Range Error | 0 | 0 | 0 | 0 |

**Figure A.1- 43 Descriptive Statistics for Flight Types at Look Ahead Time of 0 and Samples at All Altitudes**

| LOOKAHEAD TIME | | | 300 Seconds | |
|---|---|---|---|---|
| Flight type | OVR | ARR | DEP | INR |
| Sample Quantity | 16297 | 6921 | 6011 | 570 |
| Avg. Horz. Error | 2.78 | 3.54 | 3.79 | 3.01 |
| Stddev. Horz. Error | 3.11 | 3.9 | 3.46 | 2.66 |
| Max. Horz. Error | 84.31 | 65.56 | 29.61 | 18.52 |
| Min. Horz. Error | 0.01 | 0.02 | 0.02 | 0.03 |
| Avg. Lat. Error | -0.09 | -0.06 | -0.19 | 0.35 |
| Stddev. Lat. Error | 3.51 | 3.89 | 3.75 | 3.02 |
| Max. Lat. Error | 65.49 | 27.77 | 26.17 | 16.91 |
| Min. Lat. Error | -36.73 | -39.47 | -23.37 | -13.13 |
| Avg. Abs. Lat. Error | 1.87 | 2.1 | 2.14 | 1.89 |
| Stddev. Abs. Lat. Error | 2.97 | 3.27 | 3.09 | 2.38 |
| Max. Abs. Lat. Error | 65.49 | 39.47 | 26.17 | 16.91 |
| Min. Abs. Lat. Error | 0 | 0 | 0 | 0 |
| Avg. Long. Error | -0.02 | -0.33 | 0.85 | 0.11 |
| Stddev. Long. Error | 2.24 | 3.53 | 3.38 | 2.63 |
| Max. Long. Error | 25.52 | 23.81 | 20.1 | 16.26 |
| Min. Long. Error | -53.1 | -65.39 | -18.17 | -12.89 |
| Avg. Abs. Long. Error | 1.51 | 2.25 | 2.48 | 1.83 |
| Stddev. Abs. Long. Error | 1.66 | 2.74 | 2.45 | 1.9 |
| Max. Abs. Long. Error | 53.1 | 65.39 | 20.1 | 16.26 |
| Min. Abs. Long. Error | 0 | 0 | 0 | 0 |
| Avg. Vert. Error | -64 | -236.17 | 383.99 | 284.81 |
| Stddev. Vert. Error | 958.43 | 2204.25 | 2063.02 | 1864.12 |
| Max. Vert. Error | 14714.2 | 34817 | 14101 | 9842.23 |
| Min. Vert. Error | -9667 | -12626.9 | -11900 | -8383 |
| Avg. Abs. Vert. Error | 321.19 | 1349.62 | 1123.14 | 1023.72 |
| Stddev. Abs. Vert. Error | 905.27 | 1758.62 | 1772.53 | 1583.15 |
| Max. Abs. Vert. Error | 14714.2 | 34817 | 14101 | 9842.23 |
| Min. Abs. Vert. Error | 0 | 0 | 0 | 0 |
| Avg. Slant Range Error | 2.79 | 3.57 | 3.81 | 3.03 |
| Stddev. Slant Range Error | 3.1 | 3.89 | 3.45 | 2.66 |
| Max. Slant Range Error | 84.34 | 65.56 | 29.61 | 18.52 |
| Min. Slant Range Error | 0.01 | 0.04 | 0.06 | 0.07 |

**Figure A.1- 44 Descriptive Statistics for Flight Types at Look Ahead Time of 300 and Samples at All Altitudes**

| | LOOKAHEAD TIME | | 600 Seconds | |
|---|---|---|---|---|
| Flight type | OVR | ARR | DEP | INR |
| Sample Quantity | 13704 | 5424 | 4416 | 420 |
| Avg. Horz. Error | 4.44 | 5.65 | 6.55 | 4.77 |
| Stddev. Horz. Error | 5.07 | 5.82 | 5.95 | 4.14 |
| Max. Horz. Error | 125.68 | 75.37 | 40.39 | 23.41 |
| Min. Horz. Error | 0.02 | 0.03 | 0.03 | 0.05 |
| Avg. Lat. Error | -0.2 | -0.05 | -0.3 | 0.64 |
| Stddev. Lat. Error | 5.45 | 5.19 | 5.75 | 4.32 |
| Max. Lat. Error | 97.45 | 62.46 | 33.91 | 20.91 |
| Min. Lat. Error | -56.31 | -61.74 | -37.42 | -12.73 |
| Avg. Abs. Lat. Error | 2.82 | 2.77 | 3.16 | 2.59 |
| Stddev. Abs. Lat. Error | 4.67 | 4.39 | 4.81 | 3.51 |
| Max. Abs. Lat. Error | 97.45 | 62.46 | 37.42 | 20.91 |
| Min. Abs. Lat. Error | 0 | 0 | 0 | 0.01 |
| Avg. Long. Error | 0.05 | -0.26 | 2.04 | 0.68 |
| Stddev. Long. Error | 3.95 | 6.24 | 6.4 | 4.52 |
| Max. Long. Error | 91.73 | 73.8 | 31.85 | 21.33 |
| Min. Long. Error | -79.36 | -75.35 | -32.6 | -14.82 |
| Avg. Abs. Long. Error | 2.54 | 4.07 | 4.75 | 3.21 |
| Stddev. Abs. Long. Error | 3.03 | 4.73 | 4.75 | 3.24 |
| Max. Abs. Long. Error | 91.73 | 75.35 | 32.6 | 21.33 |
| Min. Abs. Long. Error | 0 | 0 | 0 | 0.01 |
| Avg. Vert. Error | -177.75 | -508.57 | 473.21 | 169.75 |
| Stddev. Vert. Error | 1241.07 | 2752.91 | 2422.84 | 1934.9 |
| Max. Vert. Error | 20728.9 | 28933 | 20033 | 8000 |
| Min. Vert. Error | -10000 | -15373.8 | -10295.8 | -8500 |
| Avg. Abs. Vert. Error | 436.68 | 1826.53 | 1279.1 | 1087.2 |
| Stddev. Abs. Vert. Error | 1175.23 | 2121.4 | 2111.32 | 1608.69 |
| Max. Abs. Vert. Error | 20728.9 | 28933 | 20033 | 8500 |
| Min. Abs. Vert. Error | 0 | 0 | 0 | 0 |
| Avg. Slant Range Error | 4.45 | 5.69 | 6.57 | 4.78 |
| Stddev. Slant Range Error | 5.07 | 5.81 | 5.94 | 4.14 |
| Max. Slant Range Error | 125.72 | 75.37 | 40.39 | 23.41 |
| Min. Slant Range Error | 0.02 | 0.08 | 0.03 | 0.05 |

**Figure A.1- 45 Descriptive Statistics for Flight Types at Look Ahead Time of 600 and Samples at All Altitudes**

| LOOKAHEAD TIME | | | 900 Seconds | |
|---|---|---|---|---|
| Flight type | OVR | ARR | DEP | INR |
| Sample Quantity | 11200 | 3996 | 3052 | 281 |
| Avg. Horz. Error | 6.01 | 7.47 | 9.01 | 6.14 |
| Stddev. Horz. Error | 6.89 | 7.29 | 8.25 | 4.99 |
| Max. Horz. Error | 167.79 | 92.08 | 71.45 | 22.86 |
| Min. Horz. Error | 0.02 | 0.05 | 0.06 | 0.09 |
| Avg. Lat. Error | -0.31 | 0.13 | -0.47 | 1.32 |
| Stddev. Lat. Error | 7.16 | 5.95 | 7.63 | 5.14 |
| Max. Lat. Error | 129.48 | 64.16 | 43.07 | 22.69 |
| Min. Lat. Error | -94.55 | -56.43 | -71.04 | -13.74 |
| Avg. Abs. Lat. Error | 3.62 | 3.17 | 4.07 | 3.16 |
| Stddev. Abs. Lat. Error | 6.19 | 5.04 | 6.48 | 4.26 |
| Max. Abs. Lat. Error | 129.48 | 64.16 | 71.04 | 22.69 |
| Min. Abs. Lat. Error | 0 | 0 | 0 | 0 |
| Avg. Long. Error | 0.13 | -0.29 | 2.96 | 1.19 |
| Stddev. Long. Error | 5.67 | 8.57 | 9.05 | 5.76 |
| Max. Long. Error | 94.25 | 66.05 | 51.09 | 21.86 |
| Min. Long. Error | -106.71 | -70.79 | -49.88 | -16.05 |
| Avg. Abs. Long. Error | 3.63 | 5.74 | 6.71 | 4.24 |
| Stddev. Abs. Long. Error | 4.37 | 6.37 | 6.76 | 4.07 |
| Max. Abs. Long. Error | 106.71 | 70.79 | 51.09 | 21.86 |
| Min. Abs. Long. Error | 0 | 0 | 0 | 0.01 |
| Avg. Vert. Error | -222.75 | -437.71 | 271.32 | 56.89 |
| Stddev. Vert. Error | 1455.74 | 2965.71 | 2128.41 | 1880.16 |
| Max. Vert. Error | 30746.5 | 22083 | 15458.53 | 6881.69 |
| Min. Vert. Error | -10050 | -16419.3 | -9797.11 | -8383 |
| Avg. Abs. Vert. Error | 523.1 | 2001.31 | 1096.37 | 1143.82 |
| Stddev. Abs. Vert. Error | 1376.64 | 2231.77 | 1844.28 | 1491.74 |
| Max. Abs. Vert. Error | 30746.5 | 22083 | 15458.53 | 8383 |
| Min. Abs. Vert. Error | 0 | 0 | 0 | 0 |
| Avg. Slant Range Error | 6.02 | 7.5 | 9.02 | 6.16 |
| Stddev. Slant Range Error | 6.88 | 7.28 | 8.24 | 4.98 |
| Max. Slant Range Error | 167.86 | 92.08 | 71.45 | 22.86 |
| Min. Slant Range Error | 0.03 | 0.05 | 0.06 | 0.15 |

**Figure A.1- 46 Descriptive Statistics for Flight Types at Look Ahead Time of 900 and Samples at All Altitudes**

| | LOOKAHEAD TIME | | 1200 Seconds | |
|---|---|---|---|---|
| Flight type | OVR | ARR | DEP | INR |
| Sample Quantity | 8886 | 2752 | 2023 | 175 |
| Avg. Horz. Error | 7.4 | 8.89 | 11.2 | 6.85 |
| Stddev. Horz. Error | 8.41 | 8.69 | 10.58 | 4.94 |
| Max. Horz. Error | 173.62 | 78 | 93.06 | 22.45 |
| Min. Horz. Error | 0.02 | 0.11 | 0.05 | 0.26 |
| Avg. Lat. Error | -0.34 | 0.45 | -0.78 | 2.14 |
| Stddev. Lat. Error | 8.56 | 6.91 | 9.66 | 4.82 |
| Max. Lat. Error | 134.87 | 53.61 | 46.16 | 18.81 |
| Min. Lat. Error | -124.94 | -61.74 | -91.33 | -11.86 |
| Avg. Abs. Lat. Error | 4.23 | 3.46 | 4.86 | 3.38 |
| Stddev. Abs. Lat. Error | 7.45 | 6 | 8.38 | 4.05 |
| Max. Abs. Lat. Error | 134.87 | 61.74 | 91.33 | 18.81 |
| Min. Abs. Lat. Error | 0 | 0 | 0 | 0.01 |
| Avg. Long. Error | 0.32 | -0.24 | 3.57 | 1.29 |
| Stddev. Long. Error | 7.22 | 10.32 | 11.44 | 6.48 |
| Max. Long. Error | 96.16 | 52.72 | 65.93 | 21.87 |
| Min. Long. Error | -109.33 | -77.99 | -62.47 | -16.17 |
| Avg. Abs. Long. Error | 4.71 | 7.06 | 8.43 | 5.06 |
| Stddev. Abs. Long. Error | 5.48 | 7.54 | 8.52 | 4.24 |
| Max. Abs. Long. Error | 109.33 | 77.99 | 65.93 | 21.87 |
| Min. Abs. Long. Error | 0 | 0.01 | 0 | 0.03 |
| Avg. Vert. Error | -237.76 | -266.5 | 32.54 | 19.2 |
| Stddev. Vert. Error | 1722.27 | 3142.5 | 1905.68 | 2148.85 |
| Max. Vert. Error | 37473.73 | 16051.78 | 12600.17 | 5740.39 |
| Min. Vert. Error | -12399.1 | -15900 | -10713.8 | -8500 |
| Avg. Abs. Vert. Error | 633.63 | 2172.19 | 913.39 | 1384.14 |
| Stddev. Abs. Vert. Error | 1619.02 | 2286.1 | 1672.71 | 1640.45 |
| Max. Abs. Vert. Error | 37473.73 | 16051.78 | 12600.17 | 8500 |
| Min. Abs. Vert. Error | 0 | 0 | 0 | 0 |
| Avg. Slant Range Error | 7.41 | 8.92 | 11.2 | 6.86 |
| Stddev. Slant Range Error | 8.41 | 8.68 | 10.58 | 4.93 |
| Max. Slant Range Error | 173.7 | 78.01 | 93.06 | 22.45 |
| Min. Slant Range Error | 0.02 | 0.14 | 0.05 | 0.33 |

**Figure A.1- 47 Descriptive Statistics for Flight Types at Look Ahead Time of 1200 and Samples at All Altitudes**

| LOOKAHEAD TIME | | 1500 Seconds | | |
|---|---|---|---|---|
| Flight type | OVR | ARR | DEP | INR |
| Sample Quantity | 6640 | 1694 | 1243 | 101 |
| Avg. Horz. Error | 8.56 | 9.92 | 13.03 | 7.01 |
| Stddev. Horz. Error | 9.56 | 9.65 | 12.6 | 4.64 |
| Max. Horz. Error | 156.35 | 67.23 | 111.55 | 17.63 |
| Min. Horz. Error | 0.01 | 0.14 | 0.11 | 0.09 |
| Avg. Lat. Error | -0.42 | 0.97 | -1.18 | 2.56 |
| Stddev. Lat. Error | 9.56 | 8.28 | 10.73 | 3.96 |
| Max. Lat. Error | 120.34 | 65.64 | 57.15 | 16.08 |
| Min. Lat. Error | -143.49 | -49.76 | -85.38 | -3.86 |
| Avg. Abs. Lat. Error | 4.59 | 4.09 | 5.3 | 3 |
| Stddev. Abs. Lat. Error | 8.39 | 7.26 | 9.4 | 3.64 |
| Max. Abs. Lat. Error | 143.49 | 65.64 | 85.38 | 16.08 |
| Min. Abs. Lat. Error | 0 | 0 | 0 | 0 |
| Avg. Long. Error | 0.34 | 0.14 | 4.1 | 0.85 |
| Stddev. Long. Error | 8.55 | 11.05 | 13.98 | 6.93 |
| Max. Long. Error | 97.63 | 45.17 | 81.43 | 14.52 |
| Min. Long. Error | -99.82 | -56.73 | -71.79 | -17.58 |
| Avg. Abs. Long. Error | 5.72 | 7.67 | 10.26 | 5.5 |
| Stddev. Abs. Long. Error | 6.37 | 7.95 | 10.35 | 4.27 |
| Max. Abs. Long. Error | 99.82 | 56.73 | 81.43 | 17.58 |
| Min. Abs. Long. Error | 0 | 0 | 0 | 0.03 |
| Avg. Vert. Error | -276.73 | -380.65 | -114.87 | -226.58 |
| Stddev. Vert. Error | 1926.48 | 3273.2 | 1894.15 | 1874.91 |
| Max. Vert. Error | 38907.87 | 13000 | 10800.18 | 4711.27 |
| Min. Vert. Error | -11065.7 | -17219.3 | -8000 | -8383 |
| Avg. Abs. Vert. Error | 766.3 | 2367.34 | 882.97 | 1161.07 |
| Stddev. Abs. Vert. Error | 1789.03 | 2291.55 | 1679.51 | 1485.11 |
| Max. Abs. Vert. Error | 38907.87 | 17219.3 | 10800.18 | 8383 |
| Min. Abs. Vert. Error | 0 | 0 | 0 | 0 |
| Avg. Slant Range Error | 8.57 | 9.95 | 13.04 | 7.02 |
| Stddev. Slant Range Error | 9.56 | 9.64 | 12.6 | 4.64 |
| Max. Slant Range Error | 156.48 | 67.26 | 111.55 | 17.63 |
| Min. Slant Range Error | 0.01 | 0.16 | 0.11 | 0.21 |

**Figure A.1- 48 Descriptive Statistics for Flight Types at Look Ahead Time of 1500 and Samples at All Altitudes**

| | LOOKAHEAD TIME | | 1800 Seconds | |
|---|---|---|---|---|
| Flight type | OVR | ARR | DEP | INR |
| Sample Quantity | 4686 | 923 | 774 | 61 |
| Avg. Horz. Error | 9.46 | 10.3 | 14.38 | 8.64 |
| Stddev. Horz. Error | 10.33 | 10.3 | 13.92 | 5.68 |
| Max. Horz. Error | 169.84 | 72.73 | 112.98 | 21.74 |
| Min. Horz. Error | 0.04 | 0.22 | 0.15 | 1.21 |
| Avg. Lat. Error | -0.48 | 1.85 | -1.31 | 2.45 |
| Stddev. Lat. Error | 10.09 | 9.36 | 10.66 | 2.84 |
| Max. Lat. Error | 117.09 | 72.43 | 28.96 | 10.43 |
| Min. Lat. Error | -155.99 | -39.14 | -91.1 | -1.15 |
| Avg. Abs. Lat. Error | 4.72 | 4.61 | 5.24 | 2.53 |
| Stddev. Abs. Lat. Error | 8.93 | 8.35 | 9.37 | 2.77 |
| Max. Abs. Lat. Error | 155.99 | 72.43 | 91.1 | 10.43 |
| Min. Abs. Lat. Error | 0 | 0 | 0 | 0.06 |
| Avg. Long. Error | 0.21 | 1.08 | 4.63 | 1.35 |
| Stddev. Long. Error | 9.7 | 10.96 | 16.25 | 9.6 |
| Max. Long. Error | 98.01 | 41.28 | 81.38 | 16.86 |
| Min. Long. Error | -78.53 | -64.35 | -66.82 | -19.44 |
| Avg. Abs. Long. Error | 6.62 | 7.74 | 11.85 | 7.81 |
| Stddev. Abs. Long. Error | 7.09 | 7.83 | 12.03 | 5.66 |
| Max. Abs. Long. Error | 98.01 | 64.35 | 81.38 | 19.44 |
| Min. Abs. Long. Error | 0 | 0.02 | 0.01 | 0.46 |
| Avg. Vert. Error | -306.19 | -554.83 | -193.89 | -182.77 |
| Stddev. Vert. Error | 2109.86 | 3315.83 | 1909.9 | 1606.16 |
| Max. Vert. Error | 31668.16 | 14399.68 | 8660.28 | 2772.54 |
| Min. Vert. Error | -12044.6 | -15800 | -8416.04 | -5355.93 |
| Avg. Abs. Vert. Error | 882.07 | 2398.38 | 867.36 | 1093.59 |
| Stddev. Abs. Vert. Error | 1940.89 | 2354.66 | 1712.32 | 1182.3 |
| Max. Abs. Vert. Error | 31668.16 | 15800 | 8660.28 | 5355.93 |
| Min. Abs. Vert. Error | 0 | 0 | 0 | 0 |
| Avg. Slant Range Error | 9.48 | 10.32 | 14.39 | 8.65 |
| Stddev. Slant Range Error | 10.32 | 10.29 | 13.91 | 5.68 |
| Max. Slant Range Error | 169.84 | 72.73 | 112.98 | 21.75 |
| Min. Slant Range Error | 0.04 | 0.23 | 0.15 | 1.21 |

**Figure A.1- 49 Descriptive Statistics for Flight Types at Look Ahead Time of 1800 and Samples at All Altitudes**

| LOOKAHEAD TIME | | | 0 Seconds | |
|---|---|---|---|---|
| Flight type | OVR | ARR | DEP | INR |
| Sample Quantity | 17817 | 4349 | 3954 | 28 |
| Avg. Horz. Error | 1.15 | 1.05 | 1.19 | 0.72 |
| Stddev. Horz. Error | 0.98 | 0.78 | 0.95 | 0.53 |
| Max. Horz. Error | 42.39 | 5.75 | 11.93 | 1.97 |
| Min. Horz. Error | 0 | 0 | 0 | 0.09 |
| Avg. Lat. Error | -0.03 | 0.02 | -0.08 | 0.2 |
| Stddev. Lat. Error | 1.22 | 1.09 | 1.21 | 0.52 |
| Max. Lat. Error | 32.23 | 4.06 | 5.21 | 1.93 |
| Min. Lat. Error | -6.04 | -5.33 | -5.18 | -1.34 |
| Avg. Abs. Lat. Error | 0.81 | 0.74 | 0.86 | 0.34 |
| Stddev. Abs. Lat. Error | 0.92 | 0.8 | 0.85 | 0.44 |
| Max. Abs. Lat. Error | 32.23 | 5.33 | 5.21 | 1.93 |
| Min. Abs. Lat. Error | 0 | 0 | 0 | 0 |
| Avg. Long. Error | -0.03 | -0.08 | 0.06 | -0.01 |
| Stddev. Long. Error | 0.88 | 0.71 | 0.93 | 0.71 |
| Max. Long. Error | 9.46 | 4.3 | 11.93 | 1.59 |
| Min. Long. Error | -27.53 | -4.6 | -11.19 | -1.16 |
| Avg. Abs. Long. Error | 0.6 | 0.55 | 0.61 | 0.54 |
| Stddev. Abs. Long. Error | 0.64 | 0.46 | 0.71 | 0.45 |
| Max. Abs. Long. Error | 27.53 | 4.6 | 11.93 | 1.59 |
| Min. Abs. Long. Error | 0 | 0 | 0 | 0.01 |
| Avg. Vert. Error | 32.33 | 33.57 | 73.39 | 65.94 |
| Stddev. Vert. Error | 510.26 | 678.37 | 796.74 | 408.62 |
| Max. Vert. Error | 26434.39 | 36817 | 28933 | 1055.33 |
| Min. Vert. Error | -2264.79 | -2045.36 | -2800 | -817.64 |
| Avg. Abs. Vert. Error | 97.56 | 210.85 | 232.04 | 226.69 |
| Stddev. Abs. Vert. Error | 501.89 | 645.64 | 765.72 | 343.78 |
| Max. Abs. Vert. Error | 26434.39 | 36817 | 28933 | 1055.33 |
| Min. Abs. Vert. Error | 0 | 0 | 0 | 0 |
| Avg. Slant Range Error | 1.15 | 1.05 | 1.2 | 0.72 |
| Stddev. Slant Range Error | 0.98 | 0.78 | 0.96 | 0.53 |
| Max. Slant Range Error | 42.39 | 6.06 | 11.93 | 1.97 |
| Min. Slant Range Error | 0 | 0 | 0 | 0.09 |

**Figure A.1- 50 Descriptive Statistics for Flight Types at Look Ahead Time of 0 and Samples at Altitudes Above 18,000 Feet**

| LOOKAHEAD TIME | | | 300 Seconds | |
|---|---|---|---|---|
| Flight type | OVR | ARR | DEP | INR |
| Sample Quantity | 15321 | 3239 | 3913 | 27 |
| Avg. Horz. Error | 2.83 | 3.66 | 4.16 | 3.34 |
| Stddev. Horz. Error | 3.17 | 4.6 | 3.68 | 2.56 |
| Max. Horz. Error | 84.31 | 65.56 | 29.61 | 9.35 |
| Min. Horz. Error | 0.01 | 0.02 | 0.02 | 0.03 |
| Avg. Lat. Error | -0.07 | -0.13 | -0.31 | 0.16 |
| Stddev. Lat. Error | 3.59 | 4.42 | 4.05 | 1.01 |
| Max. Lat. Error | 65.49 | 27.77 | 26.17 | 2.21 |
| Min. Lat. Error | -36.73 | -39.47 | -23.37 | -2.91 |
| Avg. Abs. Lat. Error | 1.91 | 2.28 | 2.26 | 0.64 |
| Stddev. Abs. Lat. Error | 3.05 | 3.79 | 3.37 | 0.79 |
| Max. Abs. Lat. Error | 65.49 | 39.47 | 26.17 | 2.91 |
| Min. Abs. Lat. Error | 0 | 0 | 0 | 0.01 |
| Avg. Long. Error | -0.02 | -0.36 | 1.1 | 1.76 |
| Stddev. Long. Error | 2.27 | 3.86 | 3.62 | 3.73 |
| Max. Long. Error | 25.52 | 23.81 | 20.1 | 9.35 |
| Min. Long. Error | -53.1 | -65.39 | -16.88 | -4.1 |
| Avg. Abs. Long. Error | 1.53 | 2.22 | 2.78 | 3.11 |
| Stddev. Abs. Long. Error | 1.68 | 3.19 | 2.58 | 2.65 |
| Max. Abs. Long. Error | 53.1 | 65.39 | 20.1 | 9.35 |
| Min. Abs. Long. Error | 0 | 0 | 0 | 0.01 |
| Avg. Vert. Error | -62.08 | 198.19 | 402.09 | 2824.39 |
| Stddev. Vert. Error | 955.2 | 2171.12 | 2092.56 | 3199.69 |
| Max. Vert. Error | 14714.2 | 34817 | 14101 | 9842.23 |
| Min. Vert. Error | -9667 | -9892.71 | -10304.6 | -1000 |
| Avg. Abs. Vert. Error | 317.63 | 1226.61 | 1151.8 | 3036.92 |
| Stddev. Abs. Vert. Error | 902.98 | 1802.22 | 1792.63 | 2990.73 |
| Max. Abs. Vert. Error | 14714.2 | 34817 | 14101 | 9842.23 |
| Min. Abs. Vert. Error | 0 | 0 | 0 | 0 |
| Avg. Slant Range Error | 2.84 | 3.69 | 4.18 | 3.48 |
| Stddev. Slant Range Error | 3.17 | 4.59 | 3.67 | 2.46 |
| Max. Slant Range Error | 84.34 | 65.56 | 29.61 | 9.35 |
| Min. Slant Range Error | 0.01 | 0.04 | 0.06 | 0.88 |

**Figure A.1- 51 Descriptive Statistics for Flight Types at Look Ahead Time of 300 and Samples at Altitudes Above 18,000 Feet**

| LOOKAHEAD TIME | | 600 Seconds | | |
|---|---|---|---|---|
| Flight type | OVR | ARR | DEP | INR |
| Sample Quantity | 12874 | 2180 | 3140 | 16 |
| Avg. Horz. Error | 4.55 | 5.87 | 7.51 | 7.05 |
| Stddev. Horz. Error | 5.18 | 6.7 | 6.32 | 6.02 |
| Max. Horz. Error | 125.68 | 75.37 | 40.39 | 19.11 |
| Min. Horz. Error | 0.02 | 0.05 | 0.03 | 0.56 |
| Avg. Lat. Error | -0.18 | -0.17 | -0.52 | 0.7 |
| Stddev. Lat. Error | 5.59 | 6.26 | 6.37 | 1.85 |
| Max. Lat. Error | 97.45 | 62.46 | 33.91 | 6.81 |
| Min. Lat. Error | -56.31 | -61.74 | -37.42 | -1.68 |
| Avg. Abs. Lat. Error | 2.9 | 3.27 | 3.56 | 1.02 |
| Stddev. Abs. Lat. Error | 4.79 | 5.34 | 5.3 | 1.68 |
| Max. Abs. Lat. Error | 97.45 | 62.46 | 37.42 | 6.81 |
| Min. Abs. Lat. Error | 0 | 0 | 0 | 0.01 |
| Avg. Long. Error | 0.04 | -0.55 | 2.5 | 4.59 |
| Stddev. Long. Error | 4.02 | 6.3 | 7.02 | 7.93 |
| Max. Long. Error | 91.73 | 26.87 | 31.85 | 19.01 |
| Min. Long. Error | -79.36 | -75.35 | -28.52 | -4.76 |
| Avg. Abs. Long. Error | 2.59 | 3.89 | 5.48 | 6.85 |
| Stddev. Abs. Long. Error | 3.08 | 4.99 | 5.05 | 5.94 |
| Max. Abs. Long. Error | 91.73 | 75.35 | 31.85 | 19.01 |
| Min. Abs. Long. Error | 0 | 0 | 0 | 0.52 |
| Avg. Vert. Error | -168.77 | 175.38 | 627.24 | 3707.17 |
| Stddev. Vert. Error | 1227.7 | 2729.41 | 2684.06 | 3264.89 |
| Max. Vert. Error | 20728.9 | 28933 | 20033 | 8000 |
| Min. Vert. Error | -10000 | -10552 | -9233 | -1000 |
| Avg. Abs. Vert. Error | 426.3 | 1703.61 | 1525.93 | 3934.42 |
| Stddev. Abs. Vert. Error | 1163.61 | 2139.35 | 2295.33 | 2967.69 |
| Max. Abs. Vert. Error | 20728.9 | 28933 | 20033 | 8000 |
| Min. Abs. Vert. Error | 0 | 0 | 0 | 0 |
| Avg. Slant Range Error | 4.56 | 5.9 | 7.53 | 7.16 |
| Stddev. Slant Range Error | 5.18 | 6.68 | 6.31 | 5.94 |
| Max. Slant Range Error | 125.72 | 75.37 | 40.39 | 19.11 |
| Min. Slant Range Error | 0.02 | 0.08 | 0.03 | 0.7 |

**Figure A.1- 52 Descriptive Statistics for Flight Types at Look Ahead Time of 600 and Samples at Altitudes Above 18,000 Feet**

| LOOKAHEAD TIME | | | 900 Seconds | |
|---|---|---|---|---|
| Flight type | OVR | ARR | DEP | INR |
| Sample Quantity | 10484 | 1330 | 2151 | 7 |
| Avg. Horz. Error | 6.18 | 7.69 | 10.51 | 5.47 |
| Stddev. Horz. Error | 7.05 | 8.61 | 8.73 | 7.42 |
| Max. Horz. Error | 167.79 | 92.08 | 71.45 | 21.97 |
| Min. Horz. Error | 0.03 | 0.06 | 0.09 | 0.98 |
| Avg. Lat. Error | -0.26 | 0.34 | -0.75 | 0.74 |
| Stddev. Lat. Error | 7.36 | 7.41 | 8.66 | 0.76 |
| Max. Lat. Error | 129.48 | 64.16 | 43.07 | 2.13 |
| Min. Lat. Error | -94.55 | -56.43 | -71.04 | -0.03 |
| Avg. Abs. Lat. Error | 3.74 | 3.9 | 4.77 | 0.75 |
| Stddev. Abs. Lat. Error | 6.34 | 6.31 | 7.27 | 0.75 |
| Max. Abs. Lat. Error | 129.48 | 64.16 | 71.04 | 2.13 |
| Min. Abs. Lat. Error | 0 | 0 | 0 | 0.03 |
| Avg. Long. Error | 0.12 | -1 | 3.55 | 2.14 |
| Stddev. Long. Error | 5.79 | 8.79 | 9.93 | 9.14 |
| Max. Long. Error | 94.25 | 66.05 | 51.09 | 21.86 |
| Min. Long. Error | -106.71 | -70.79 | -42.99 | -4.77 |
| Avg. Abs. Long. Error | 3.7 | 5.35 | 7.79 | 5.4 |
| Stddev. Abs. Long. Error | 4.45 | 7.04 | 7.11 | 7.41 |
| Max. Abs. Long. Error | 106.71 | 70.79 | 51.09 | 21.86 |
| Min. Abs. Long. Error | 0 | 0 | 0 | 0.98 |
| Avg. Vert. Error | -199.89 | 438.42 | 409.32 | 5089.34 |
| Stddev. Vert. Error | 1437.65 | 3093.88 | 2395.8 | 1556.09 |
| Max. Vert. Error | 30746.5 | 22083 | 15458.53 | 6881.69 |
| Min. Vert. Error | -9700 | -10700 | -9797.11 | 3000 |
| Avg. Abs. Vert. Error | 504.46 | 2025.65 | 1333.17 | 5089.34 |
| Stddev. Abs. Vert. Error | 1361 | 2378.67 | 2032.07 | 1556.09 |
| Max. Abs. Vert. Error | 30746.5 | 22083 | 15458.53 | 6881.69 |
| Min. Abs. Vert. Error | 0 | 0 | 0 | 3000 |
| Avg. Slant Range Error | 6.19 | 7.72 | 10.53 | 5.65 |
| Stddev. Slant Range Error | 7.04 | 8.6 | 8.72 | 7.33 |
| Max. Slant Range Error | 167.86 | 92.08 | 71.45 | 21.97 |
| Min. Slant Range Error | 0.03 | 0.11 | 0.09 | 1.38 |

**Figure A.1- 53 Descriptive Statistics for Flight Types at Look Ahead Time of 900 and Samples at Altitudes Above 18,000 Feet**

| LOOKAHEAD TIME | | | 1200 Seconds | |
|---|---|---|---|---|
| Flight type | OVR | ARR | DEP | INR |
| Sample Quantity | 8279 | 729 | 1365 | 1 |
| Avg. Horz. Error | 7.6 | 8.71 | 13.43 | 2.45 |
| Stddev. Horz. Error | 8.61 | 10.08 | 11.25 | 0 |
| Max. Horz. Error | 173.62 | 78 | 93.06 | 2.45 |
| Min. Horz. Error | 0.02 | 0.16 | 0.05 | 2.45 |
| Avg. Lat. Error | -0.27 | 1.56 | -1.21 | 0.44 |
| Stddev. Lat. Error | 8.81 | 8.46 | 11.38 | 0 |
| Max. Lat. Error | 134.87 | 53.61 | 46.16 | 0.44 |
| Min. Lat. Error | -124.94 | -61.74 | -91.33 | 0.44 |
| Avg. Abs. Lat. Error | 4.37 | 4.43 | 6.06 | 0.44 |
| Stddev. Abs. Lat. Error | 7.65 | 7.37 | 9.7 | 0 |
| Max. Abs. Lat. Error | 134.87 | 61.74 | 91.33 | 0.44 |
| Min. Abs. Lat. Error | 0 | 0 | 0 | 0.44 |
| Avg. Long. Error | 0.3 | -0.39 | 4.48 | -2.41 |
| Stddev. Long. Error | 7.37 | 10.18 | 12.49 | 0 |
| Max. Long. Error | 96.16 | 52.53 | 65.93 | -2.41 |
| Min. Long. Error | -109.33 | -77.99 | -46.22 | -2.41 |
| Avg. Abs. Long. Error | 4.82 | 6.06 | 9.88 | 2.41 |
| Stddev. Abs. Long. Error | 5.59 | 8.18 | 8.85 | 0 |
| Max. Abs. Long. Error | 109.33 | 77.99 | 65.93 | 2.41 |
| Min. Abs. Long. Error | 0 | 0.01 | 0 | 2.41 |
| Avg. Vert. Error | -198.02 | 579.37 | 104.24 | 5507.95 |
| Stddev. Vert. Error | 1698.4 | 3291.49 | 2134.86 | 0 |
| Max. Vert. Error | 37473.73 | 16051.78 | 12600.17 | 5507.95 |
| Min. Vert. Error | -8800 | -9350 | -10485.7 | 5507.95 |
| Avg. Abs. Vert. Error | 605.09 | 2138.76 | 1086.58 | 5507.95 |
| Stddev. Abs. Vert. Error | 1599.25 | 2567 | 1840.37 | 0 |
| Max. Abs. Vert. Error | 37473.73 | 16051.78 | 12600.17 | 5507.95 |
| Min. Abs. Vert. Error | 0 | 0 | 0 | 5507.95 |
| Avg. Slant Range Error | 7.61 | 8.75 | 13.43 | 2.61 |
| Stddev. Slant Range Error | 8.61 | 10.06 | 11.25 | 0 |
| Max. Slant Range Error | 173.7 | 78.01 | 93.06 | 2.61 |
| Min. Slant Range Error | 0.02 | 0.16 | 0.05 | 2.61 |

**Figure A.1- 54 Descriptive Statistics for Flight Types at Look Ahead Time of 1200 and Samples at Altitudes Above 18,000 Feet**

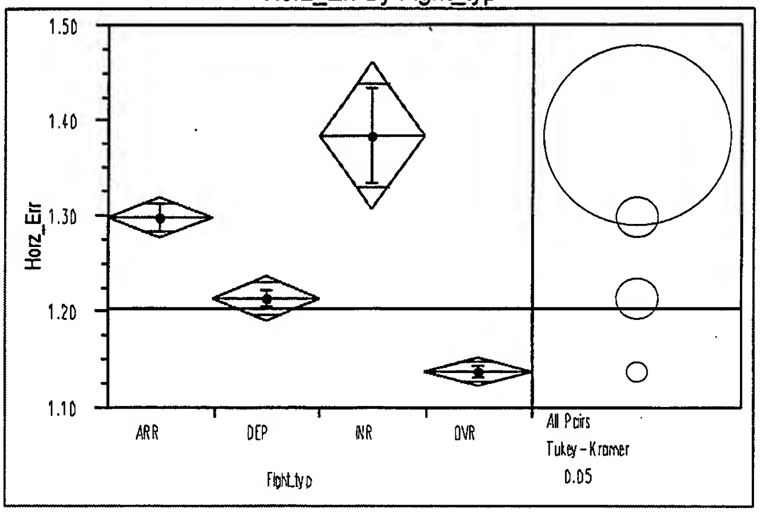
| LOOKAHEAD TIME | | 1500 Seconds | | |
|---|---|---|---|---|
| Flight type | OVR | ARR | DEP | INR |
| Sample Quantity | 6125 | 385 | 797 | 0 |
| Avg. Horz. Error | 8.81 | 9.26 | 16.24 | 0 |
| Stddev. Horz. Error | 9.83 | 10.56 | 13.8 | 0 |
| Max. Horz. Error | 156.35 | 67.23 | 111.55 | 0 |
| Min. Horz. Error | 0.01 | 0.22 | 0.16 | 0 |
| Avg. Lat. Error | -0.34 | 2.24 | -1.99 | 0 |
| Stddev. Lat. Error | 9.87 | 9.38 | 12.89 | 0 |
| Max. Lat. Error | 120.34 | 65.64 | 57.15 | 0 |
| Min. Lat. Error | -143.49 | -49.76 | -85.38 | 0 |
| Avg. Abs. Lat. Error | 4.75 | 4.81 | 6.85 | 0 |
| Stddev. Abs. Lat. Error | 8.66 | 8.35 | 11.1 | 0 |
| Max. Abs. Lat. Error | 143.49 | 65.64 | 85.38 | 0 |
| Min. Abs. Lat. Error | 0 | 0.02 | 0 | 0 |
| Avg. Long. Error | 0.31 | 0.18 | 5.52 | 0 |
| Stddev. Long. Error | 8.76 | 10.22 | 15.94 | 0 |
| Max. Long. Error | 97.63 | 36.7 | 81.43 | 0 |
| Min. Long. Error | -99.82 | -56.73 | -71.79 | 0 |
| Avg. Abs. Long. Error | 5.86 | 6.36 | 12.58 | 0 |
| Stddev. Abs. Long. Error | 6.52 | 8 | 11.22 | 0 |
| Max. Abs. Long. Error | 99.82 | 56.73 | 81.43 | 0 |
| Min. Abs. Long. Error | 0 | 0.01 | 0.07 | 0 |
| Avg. Vert. Error | -221.3 | 640.74 | -159.15 | 0 |
| Stddev. Vert. Error | 1908.58 | 3153.86 | 2153.44 | 0 |
| Max. Vert. Error | 38907.87 | 13000 | 10800.18 | 0 |
| Min. Vert. Error | -9483.61 | -7073.06 | -7833 | 0 |
| Avg. Abs. Vert. Error | 729.55 | 2145.71 | 1053.36 | 0 |
| Stddev. Abs. Vert. Error | 1777.45 | 2396.32 | 1884.6 | 0 |
| Max. Abs. Vert. Error | 38907.87 | 13000 | 10800.18 | 0 |
| Min. Abs. Vert. Error | 0 | 0 | 0 | 0 |
| Avg. Slant Range Error | 8.82 | 9.29 | 16.25 | 0 |
| Stddev. Slant Range Error | 9.83 | 10.54 | 13.8 | 0 |
| Max. Slant Range Error | 156.48 | 67.26 | 111.55 | 0 |
| Min. Slant Range Error | 0.01 | 0.22 | 0.16 | 0 |

**Figure A.1- 55 Descriptive Statistics for Flight Types at Look Ahead Time of 1500 and Samples at Altitudes Above 18,000 Feet**

| LOOKAHEAD TIME | | 1800 Seconds | | |
|---|---|---|---|---|
| Flight type | OVR | ARR | DEP | INR |
| Sample Quantity | 4246 | 192 | 453 | 0 |
| Avg. Horz. Error | 9.77 | 9.89 | 18.89 | 0 |
| Stddev. Horz. Error | 10.69 | 11.35 | 15.51 | 0 |
| Max. Horz. Error | 169.84 | 65.77 | 112.98 | 0 |
| Min. Horz. Error | 0.04 | 0.28 | 0.19 | 0 |
| Avg. Lat. Error | -0.36 | 2.46 | -2.42 | 0 |
| Stddev. Lat. Error | 10.48 | 9.21 | 13.26 | 0 |
| Max. Lat. Error | 117.09 | 53.61 | 28.96 | 0 |
| Min. Lat. Error | -155.99 | -12.52 | -91.1 | 0 |
| Avg. Abs. Lat. Error | 4.88 | 4.87 | 7.05 | 0 |
| Stddev. Abs. Lat. Error | 9.28 | 8.19 | 11.49 | 0 |
| Max. Abs. Lat. Error | 155.99 | 53.61 | 91.1 | 0 |
| Min. Abs. Lat. Error | 0 | 0 | 0 | 0 |
| Avg. Long. Error | 0.12 | -0.28 | 7.36 | 0 |
| Stddev. Long. Error | 9.99 | 11.67 | 19.03 | 0 |
| Max. Long. Error | 98.01 | 41.28 | 81.38 | 0 |
| Min. Long. Error | -78.53 | -64.35 | -66.82 | 0 |
| Avg. Abs. Long. Error | 6.82 | 6.8 | 15.42 | 0 |
| Stddev. Abs. Long. Error | 7.29 | 9.47 | 13.34 | 0 |
| Max. Abs. Long. Error | 98.01 | 64.35 | 81.38 | 0 |
| Min. Abs. Long. Error | 0 | 0.1 | 0.01 | 0 |
| Avg. Vert. Error | -214.25 | 915.07 | -325 | 0 |
| Stddev. Vert. Error | 2071.27 | 3306.58 | 2054.36 | 0 |
| Max. Vert. Error | 31668.16 | 14399.68 | 8660.28 | 0 |
| Min. Vert. Error | -10550 | -5633 | -7900 | 0 |
| Avg. Abs. Vert. Error | 823.12 | 2281.02 | 964.54 | 0 |
| Stddev. Abs. Vert. Error | 1912.69 | 2558.31 | 1842.24 | 0 |
| Max. Abs. Vert. Error | 31668.16 | 14399.68 | 8660.28 | 0 |
| Min. Abs. Vert. Error | 0 | 0 | 0 | 0 |
| Avg. Slant Range Error | 9.78 | 9.92 | 18.89 | 0 |
| Stddev. Slant Range Error | 10.68 | 11.34 | 15.51 | 0 |
| Max. Slant Range Error | 169.84 | 65.81 | 112.98 | 0 |
| Min. Slant Range Error | 0.04 | 0.69 | 0.39 | 0 |

**Figure A.1- 56 Descriptive Statistics for Flight Types at Look Ahead Time of 1800 and Samples at Altitudes Above 18,000 Feet**

### A.1.2.2 Statistical Tests




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 8448 | 1.30677 | 1.39839 | 0.01521 |
| DEP | 7726 | 1.21862 | 0.91280 | 0.01038 |
| INR | 739 | 1.39209 | 1.39924 | 0.05147 |
| OVR | 19015 | 1.14659 | 0.96289 | 0.00698 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | INR | ARR | DEP | OVR |
|---|---|---|---|---|
| INR | 0.000000 | 0.085314 | 0.173462 | 0.245493 |
| ARR | -0.08531 | 0.000000 | 0.088149 | 0.160180 |
| DEP | -0.17346 | -0.08815 | 0.000000 | 0.072031 |
| OVR | -0.24549 | -0.16018 | -0.07203 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.56915

| Abs(Dif)-LSD | INR | ARR | DEP | OVR |
|---|---|---|---|---|
| INR | -0.14456 | -0.02129 | 0.066462 | 0.141303 |
| ARR | -0.02129 | -0.04276 | 0.044404 | 0.123845 |
| DEP | 0.066462 | 0.044404 | -0.04471 | 0.034540 |
| OVR | 0.141303 | 0.123845 | 0.034540 | -0.0285 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 8448 | 1.398387 | 0.8735268 | 0.8128893 |
| DEP | 7726 | 0.912805 | 0.6773466 | 0.6614614 |
| INR | 739 | 1.399239 | 0.8921797 | 0.8410334 |
| OVR | 19015 | 0.962894 | 0.6522515 | 0.6309438 |

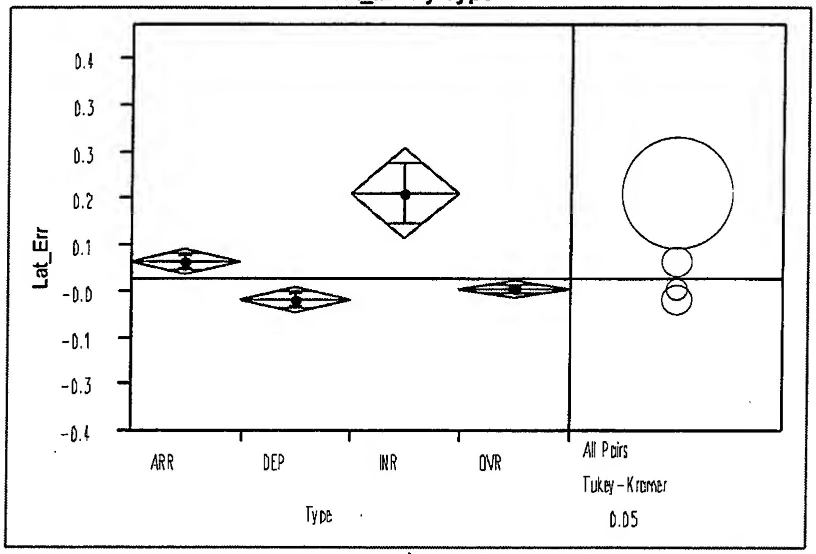
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 20.6626 | 3 | 35924 | <.0001 |
| Brown-Forsythe | 94.8825 | 3 | 35924 | <.0001 |
| Levene | 164.7150 | 3 | 35924 | <.0001 |
| Bartlett | 774.7981 | 3 | ? | 0.0000 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 40.1530 | 3 | 3346.9 | <.0001 |

**Figure A.1- 57 Statistical Tests for Horizontal Error and Flight Type at Look Ahead 0 for Samples at All Altitudes**

Lat_Err By Type




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 8448 | 0.027652 | 1.61241 | 0.01754 |
| DEP | 7726 | -0.0661 | 1.25060 | 0.01423 |
| INR | 739 | 0.172656 | 1.76404 | 0.06489 |
| OVR | 19015 | -0.03539 | 1.22071 | 0.00885 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | INR | ARR | OVR | DEP |
|---|---|---|---|---|
| INR | 0.000000 | 0.145004 | 0.208051 | 0.238760 |
| ARR | -0.145 | 0.000000 | 0.063046 | 0.093756 |
| OVR | -0.20805 | -0.06305 | 0.000000 | 0.030710 |
| DEP | -0.23876 | -0.09376 | -0.03071 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.56915

| Abs(Dif)-LSD | INR | ARR | OVR | DEP |
|---|---|---|---|---|
| INR | -0.17933 | 0.012769 | 0.078805 | 0.106029 |
| ARR | 0.012769 | -0.05304 | 0.017974 | 0.039492 |
| OVR | 0.078805 | 0.017974 | -0.03535 | -0.0158 |
| DEP | 0.106029 | 0.039492 | -0.0158 | -0.05546 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

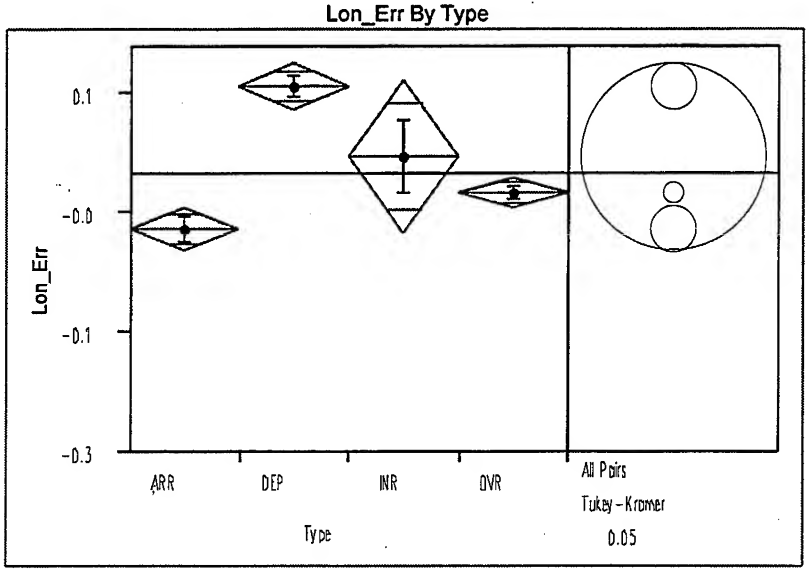
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 8448 | 1.612409 | 0.939075 | 0.938874 |
| DEP | 7726 | 1.250601 | 0.915938 | 0.914665 |
| INR | 739 | 1.764038 | 1.120226 | 1.119173 |
| OVR | 19015 | 1.220712 | 0.813887 | 0.813112 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 44.6490 | 3 | 35924 | <.0001 |
| Brown-Forsythe | 52.2906 | 3 | 35924 | <.0001 |
| Levene | 52.3370 | 3 | 35924 | <.0001 |
| Bartlett | 391.0798 | 3 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 9.1155 | 3 | 3346.5 | <.0001 |

**Figure A.1- 58 Statistical Tests for Lateral Error and Flight Type at Look Ahead 0 for Samples at All Altitudes**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 8448 | -0.06119 | 1.02906 | 0.01120 |
| DEP | 7726 | 0.059377 | 0.86403 | 0.00983 |
| INR | 739 | -0.00021 | 0.86989 | 0.03200 |
| OVR | 19015 | -0.02707 | 0.86590 | 0.00628 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | DEP | INR | OVR | ARR |
|---|---|---|---|---|
| DEP | 0.000000 | 0.059585 | 0.086450 | 0.120567 |
| INR | -0.05959 | 0.000000 | 0.026864 | 0.060982 |
| OVR | -0.08645 | -0.02686 | 0.000000 | 0.034117 |
| ARR | -0.12057 | -0.06098 | -0.03412 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.56915

| Abs(Dif)-LSD | DEP | INR | OVR | ARR |
|---|---|---|---|---|
| DEP | -0.03748 | -0.0301 | 0.055025 | 0.083901 |
| INR | -0.0301 | -0.12117 | -0.06047 | -0.02837 |
| OVR | 0.055025 | -0.06047 | -0.02389 | 0.003663 |
| ARR | 0.083901 | -0.02837 | 0.003663 | -0.03584 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

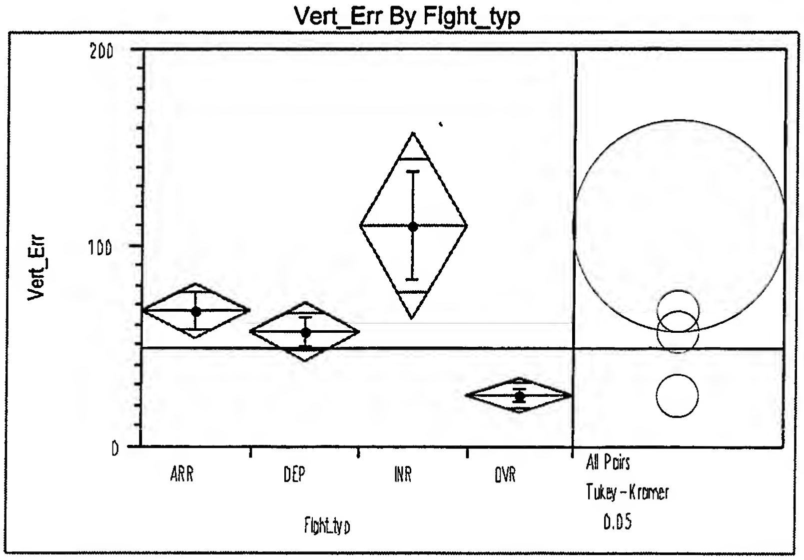
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 8448 | 1.029061 | 0.6658010 | 0.6657831 |
| DEP | 7726 | 0.864030 | 0.5779702 | 0.5778819 |
| INR | 739 | 0.869889 | 0.5829329 | 0.5829153 |
| OVR | 19015 | 0.865901 | 0.5939413 | 0.5938627 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 5.5325 | 3 | 35924 | 0.0009 |
| Brown-Forsythe | 29.0760 | 3 | 35924 | <.0001 |
| Levene | 29.0404 | 3 | 35924 | <.0001 |
| Bartlett | 136.8188 | 3 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 25.9604 | 3 | 3418.8 | <.0001 |

**Figure A.1- 59 Statistical Tests for Longitudinal Error and Flight Type at Look Ahead 0 for Samples at All Altitudes**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 8448 | 70.188 | 925.088 | 10.065 |
| DEP | 7726 | 61.550 | 660.830 | 7.518 |
| INR | 739 | 121.234 | 758.396 | 27.898 |
| OVR | 19015 | 32.353 | 499.734 | 3.624 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | INR | ARR | DEP | OVR |
|---|---|---|---|---|
| INR | 0.0000 | 51.0458 | 59.6838 | 88.8804 |
| ARR | -51.0458 | 0.0000 | 8.6380 | 37.8346 |
| DEP | -59.6838 | -8.6380 | 0.0000 | 29.1965 |
| OVR | -88.8804 | -37.8346 | -29.1965 | 0.0000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.56915

| Abs(Dif)-LSD | INR | ARR | DEP | OVR |
|---|---|---|---|---|
| INR | -88.5683 | -14.2632 | -5.8702 | 25.0478 |
| ARR | -14.2632 | -26.1953 | -18.1623 | 15.5741 |
| DEP | -5.8702 | -18.1623 | -27.3920 | 6.2272 |
| OVR | 25.0478 | 15.5741 | 6.2272 | -17.4603 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

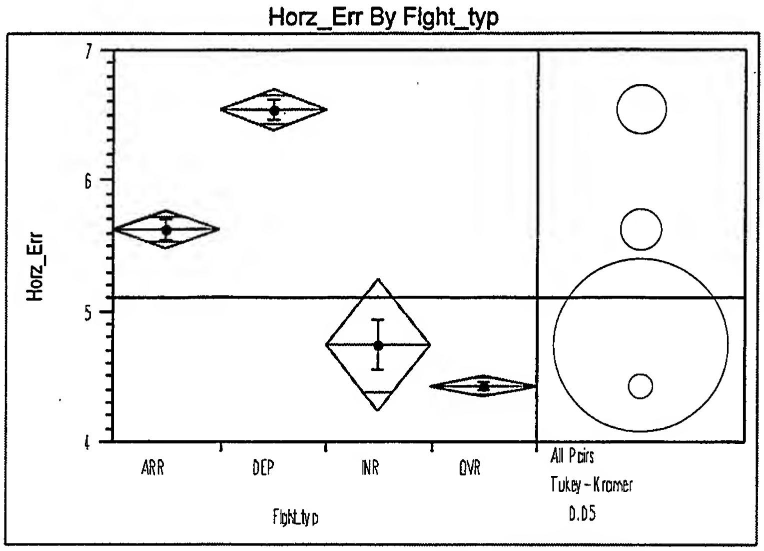
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 8448 | 925.0881 | 399.3161 | 373.8933 |
| DEP | 7726 | 660.8301 | 279.6681 | 261.3665 |
| INR | 739 | 758.3961 | 353.6892 | 328.3434 |
| OVR | 19015 | 499.7343 | 122.1939 | 100.6145 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 6.2275 | 3 | 35924 | 0.0003 |
| Brown-Forsythe | 417.0248 | 3 | 35924 | <.0001 |
| Levene | 438.9741 | 3 | 35924 | <.0001 |
| Bartlett | 1646.0411 | 3 | ? | 0.0000 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 9.9148 | 3 | 3305.4 | <.0001 |

**Figure A.1- 60 Statistical Tests for Vertical Error and Flight Type at Look Ahead 0 for Samples at All Altitudes**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 5424 | 5.65443 | 5.82123 | 0.07904 |
| DEP | 4416 | 6.54882 | 5.94563 | 0.08947 |
| INR | 420 | 4.76544 | 4.14447 | 0.20223 |
| OVR | 13704 | 4.43793 | 5.06903 | 0.04330 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | DEP | ARR | INR | OVR |
|---|---|---|---|---|
| DEP | 0.00000 | 0.89439 | 1.78339 | 2.11089 |
| ARR | -0.89439 | 0.00000 | 0.88900 | 1.21651 |
| INR | -1.78339 | -0.88900 | 0.00000 | 0.32751 |
| OVR | -2.11089 | -1.21651 | -0.32751 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.56921

| Abs(Dif)-LSD | DEP | ARR | INR | OVR |
|---|---|---|---|---|
| DEP | -0.29535 | 0.61309 | 1.07472 | 1.87075 |
| ARR | 0.61309 | -0.26650 | 0.18607 | 0.99387 |
| INR | 1.07472 | 0.18607 | -0.95770 | -0.35999 |
| OVR | 1.87075 | 0.99387 | -0.35999 | -0.16766 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

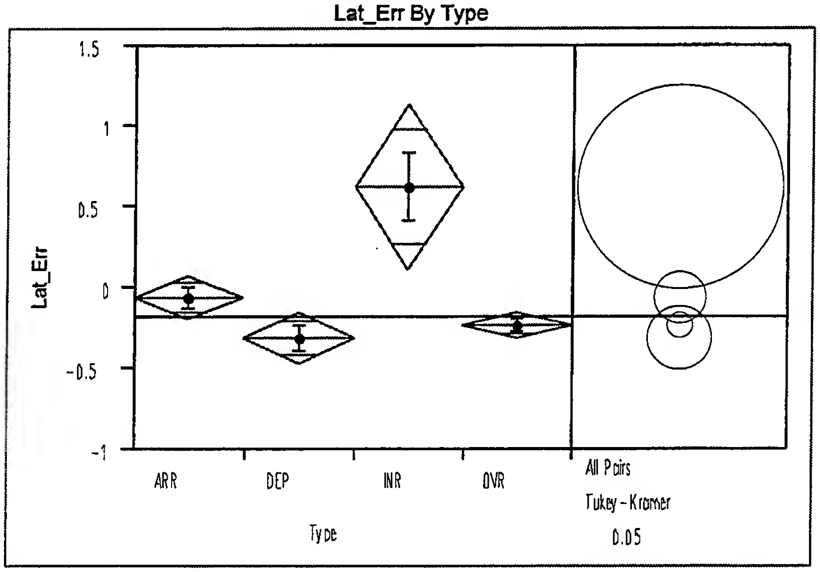
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 5424 | 5.821235 | 3.814676 | 3.577853 |
| DEP | 4416 | 5.945632 | 4.499082 | 4.253545 |
| INR | 420 | 4.144473 | 3.068972 | 2.938459 |
| OVR | 13704 | 5.069030 | 3.194342 | 2.906630 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 4.9006 | 3 | 23960 | 0.0021 |
| Brown-Forsythe | 107.3528 | 3 | 23960 | <.0001 |
| Levene | 127.4396 | 3 | 23960 | <.0001 |
| Bartlett | 102.1086 | 3 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 179.2093 | 3 | 1964.4 | <.0001 |

**Figure A.1- 61 Statistical Tests for Horizontal Error and Flight Type at Look Ahead 600 for Samples at All Altitudes**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 5424 | -0.04855 | 5.18728 | 0.07043 |
| DEP | 4416 | -0.29545 | 5.74566 | 0.08646 |
| INR | 420 | 0.639414 | 4.31964 | 0.21078 |
| OVR | 13704 | -0.204 | 5.45218 | 0.04657 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | INR | ARR | OVR | DEP |
|---|---|---|---|---|
| INR | 0.000000 | 0.687965 | 0.843415 | 0.934862 |
| ARR | -0.68796 | 0.000000 | 0.155450 | 0.246898 |
| OVR | -0.84342 | -0.15545 | 0.000000 | 0.091447 |
| DEP | -0.93486 | -0.2469 | -0.09145 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.56921

| Abs(Dif)-LSD | INR | ARR | OVR | DEP |
|---|---|---|---|---|
| INR | -0.96295 | -0.01882 | 0.152151 | 0.222308 |
| ARR | -0.01882 | -0.26796 | -0.0684 | -0.03594 |
| OVR | 0.152151 | -0.0684 | -0.16858 | -0.15002 |
| DEP | 0.222308 | -0.03594 | -0.15002 | -0.29697 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 5424 | 5.187277 | 2.768101 | 2.765340 |
| DEP | 4416 | 5.745658 | 3.188760 | 3.155276 |
| INR | 420 | 4.319640 | 2.608779 | 2.566873 |
| OVR | 13704 | 5.452177 | 2.840231 | 2.817599 |

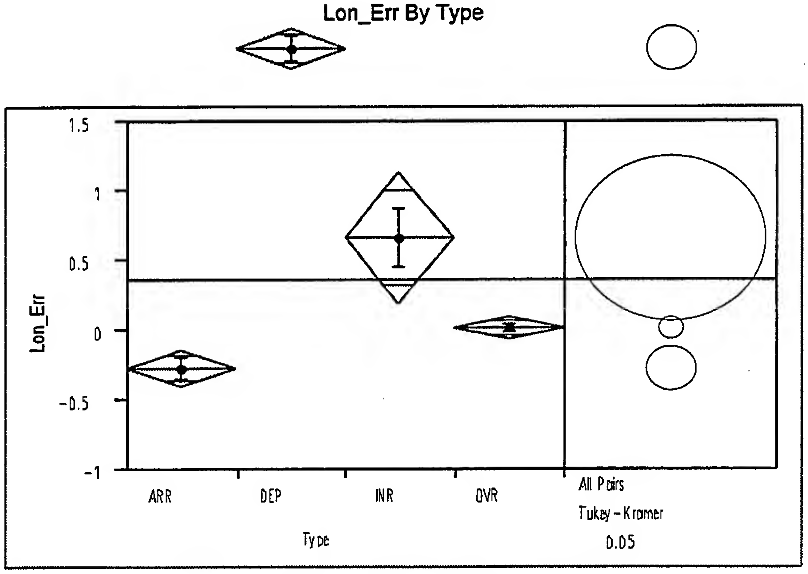
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 2.5416 | 3 | 23960 | 0.0545 |
| Brown-Forsythe | 7.7254 | 3 | 23960 | <.0001 |
| Levene | 8.5242 | 3 | 23960 | <.0001 |
| Bartlett | 29.8614 | 3 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 6.7387 | 3 | 1972.8 | 0.0002 |

**Figure A.1- 62 Statistical Tests for Lateral Error and Flight Type at Look Ahead 600 for Samples at All Altitudes**

Lon_Err By Type




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 5424 | -0.25745 | 6.23609 | 0.08467 |
| DEP | 4416 | 2.04462 | 6.40047 | 0.09632 |
| INR | 420 | 0.67902 | 4.51763 | 0.22044 |
| OVR | 13704 | 0.05435 | 3.95233 | 0.03376 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | DEP | INR | OVR | ARR |
|---|---|---|---|---|
| DEP | 0.00000 | 1.36560 | 1.99028 | 2.30208 |
| INR | -1.36560 | 0.00000 | 0.62467 | 0.93647 |
| OVR | -1.99028 | -0.62467 | 0.00000 | 0.31180 |
| ARR | -2.30208 | -0.93647 | -0.31180 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.56921

| Abs(Dif)-LSD | DEP | INR | OVR | ARR |
|---|---|---|---|---|
| DEP | -0.27687 | 0.70129 | 1.76516 | 2.03839 |
| INR | 0.70129 | -0.89776 | -0.01979 | 0.27754 |
| OVR | 1.76516 | -0.01979 | -0.15717 | 0.10310 |
| ARR | 2.03839 | 0.27754 | 0.10310 | -0.24982 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

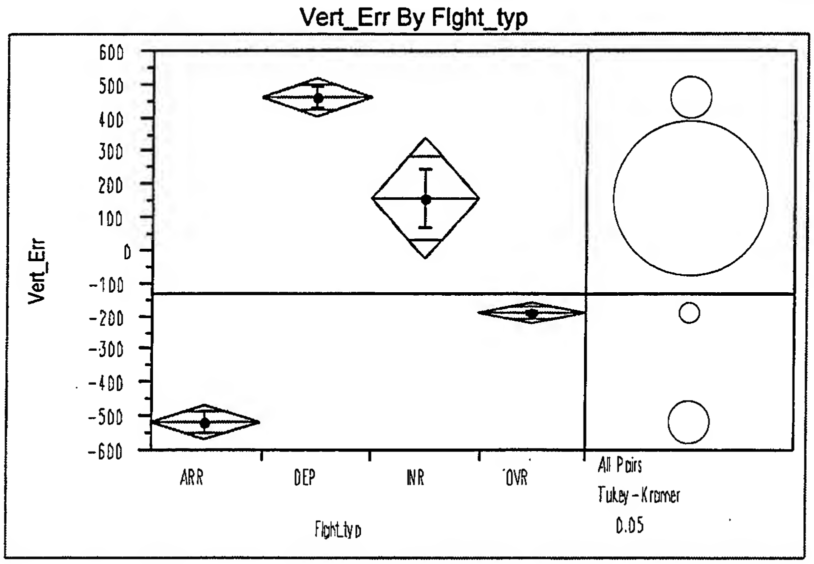
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 5424 | 6.236088 | 4.083972 | 4.070124 |
| DEP | 4416 | 6.400468 | 4.679750 | 4.616607 |
| INR | 420 | 4.517630 | 3.223334 | 3.200056 |
| OVR | 13704 | 3.952328 | 2.541685 | 2.541273 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 59.7962 | 3 | 23960 | <.0001 |
| Brown-Forsythe | 438.6663 | 3 | 23960 | <.0001 |
| Levene | 468.8180 | 3 | 23960 | <.0001 |
| Bartlett | 852.8624 | 3 | ? | 0.0000 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 139.5878 | 3 | 1898.5 | <.0001 |

**Figure A.1- 63 Statistical Tests for Longitudinal Error and Flight Type at Look Ahead 600 for Samples at All Altitudes**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 5424 | -508.568 | 2752.91 | 37.379 |
| DEP | 4416 | 473.214 | 2422.84 | 36.459 |
| INR | 420 | 169.747 | 1934.90 | 94.413 |
| OVR | 13704 | -177.748 | 1241.07 | 10.602 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | DEP | INR | OVR | ARR |
|---|---|---|---|---|
| DEP | 0.000 | 303.467 | 650.962 | 981.782 |
| INR | -303.467 | 0.000 | 347.495 | 678.315 |
| OVR | -650.962 | -347.495 | 0.000 | 330.820 |
| ARR | -981.782 | -678.315 | -330.820 | 0.000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.56921

| Abs(Dif)-LSD | DEP | INR | OVR | ARR |
|---|---|---|---|---|
| DEP | -105.786 | 49.644 | 564.948 | 881.030 |
| INR | 49.644 | -343.019 | 101.255 | 426.548 |
| OVR | 564.948 | 101.255 | -60.051 | 251.079 |
| ARR | 881.030 | 426.548 | 251.079 | -95.452 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 5424 | 2752.906 | 1885.542 | 1826.528 |
| DEP | 4416 | 2422.842 | 1473.997 | 1279.100 |
| INR | 420 | 1934.898 | 1129.098 | 1087.200 |
| OVR | 13704 | 1241.074 | 558.379 | 436.680 |

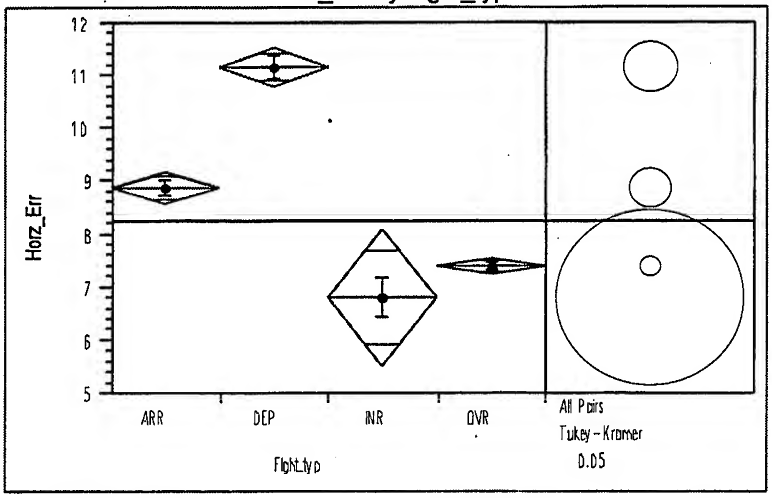
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 288.9470 | 3 | 23960 | <.0001 |
| Brown-Forsythe | 1026.7023 | 3 | 23960 | 0.0000 |
| Levene | 1125.4173 | 3 | 23960 | 0.0000 |
| Bartlett | 2118.3415 | 3 | ? | 0.0000 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 134.0774 | 3 | 1856.9 | <.0001 |

**Figure A.1- 64 Statistical Tests for Vertical Error and Flight Type at Look Ahead 600 for Samples at All Altitudes**

Horz_Err By Flght_typ




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 2752 | 8.8888 | 8.6910 | 0.16567 |
| DEP | 2023 | 11.1970 | 10.5830 | 0.23529 |
| INR | 175 | 6.8506 | 4.9372 | 0.37322 |
| OVR | 8886 | 7.4045 | 8.4128 | 0.08925 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | DEP | ARR | OVR | INR |
|---|---|---|---|---|
| DEP | 0.00000 | 2.30816 | 3.79246 | 4.34642 |
| ARR | -2.30816 | 0.00000 | 1.48430 | 2.03826 |
| OVR | -3.79246 | -1.48430 | 0.00000 | 0.55396 |
| INR | -4.34642 | -2.03826 | -0.55396 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.56934

| Abs(Dif)-LSD | DEP | ARR | OVR | INR |
|---|---|---|---|---|
| DEP | -0.70965 | 1.64717 | 3.23647 | 2.56804 |
| ARR | 1.64717 | -0.60844 | 0.99193 | 0.27873 |
| OVR | 3.23647 | 0.99193 | -0.33860 | -1.16887 |
| INR | 2.56804 | 0.27873 | -1.16887 | -2.41282 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

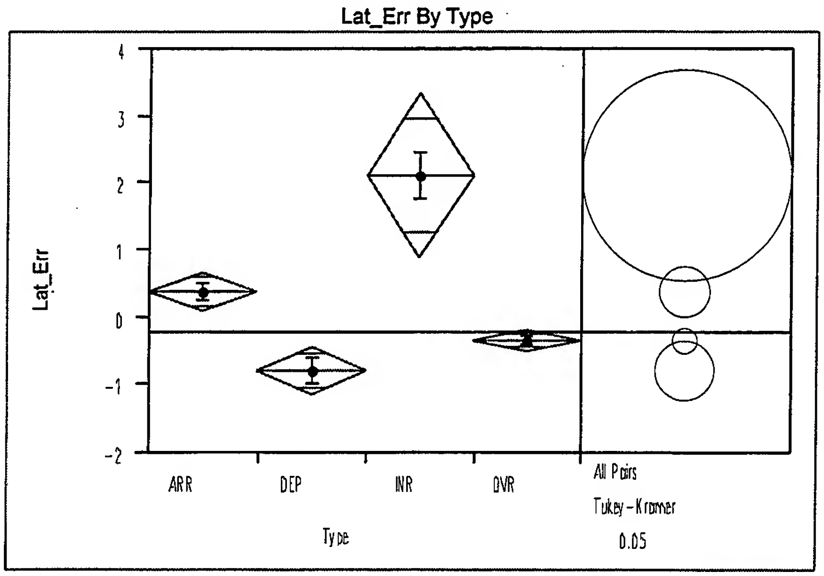
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 2752 | 8.69101 | 6.045259 | 5.670412 |
| DEP | 2023 | 10.58296 | 7.855500 | 7.408243 |
| INR | 175 | 4.93723 | 4.010688 | 3.978116 |
| OVR | 8886 | 8.41275 | 5.165765 | 4.768198 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 4.2481 | 3 | 13832 | 0.0052 |
| Brown-Forsythe | 74.8990 | 3 | 13832 | <.0001 |
| Levene | 97.7130 | 3 | 13832 | <.0001 |
| Bartlett | 91.2170 | 3 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 88.9024 | 3 | 838 | <.0001 |

**Figure A.1- 65 Statistical Tests for Horizontal Error and Flight Type at Look Ahead 1200 for Samples at All Altitudes**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 2752 | 0.44933 | 6.90750 | 0.13167 |
| DEP | 2023 | -0.77607 | 9.65818 | 0.21473 |
| INR | 175 | 2.13575 | 4.82428 | 0.36468 |
| OVR | 8886 | -0.33598 | 8.55880 | 0.09079 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | INR | ARR | OVR | DEP |
|---|---|---|---|---|
| INR | 0.00000 | 1.68642 | 2.47173 | 2.91182 |
| ARR | -1.68642 | 0.00000 | 0.78532 | 1.22540 |
| OVR | -2.47173 | -0.78532 | 0.00000 | 0.44008 |
| DEP | -2.91182 | -1.22540 | -0.44008 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.56934

| Abs(Dif)-LSD | INR | ARR | OVR | DEP |
|---|---|---|---|---|
| INR | -2.30583 | 0.00491 | 0.82529 | 1.21229 |
| ARR | 0.00491 | -0.58146 | 0.31478 | 0.59372 |
| OVR | 0.82529 | 0.31478 | -0.32359 | -0.09126 |
| DEP | 1.21229 | 0.59372 | -0.09126 | -0.67819 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 2752 | 6.907495 | 3.510546 | 3.454990 |
| DEP | 2023 | 9.658175 | 5.029599 | 4.861608 |
| INR | 175 | 4.824283 | 3.566948 | 3.217192 |
| OVR | 8886 | 8.558796 | 4.282437 | 4.228983 |

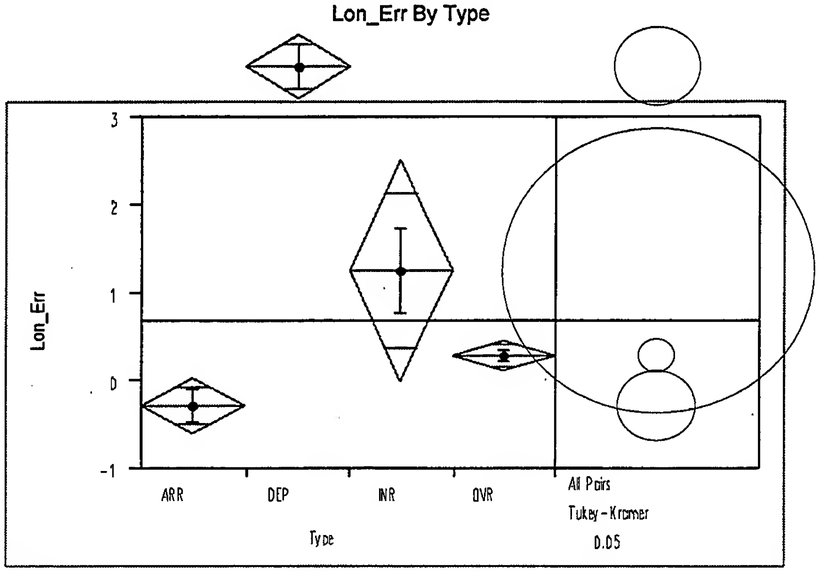
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 5.9916 | 3 | 13832 | 0.0004 |
| Brown-Forsythe | 16.0369 | 3 | 13832 | <.0001 |
| Levene | 17.9417 | 3 | 13832 | <.0001 |
| Bartlett | 118.2192 | 3 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 23.8050 | 3 | 840.91 | <.0001 |

**Figure A.1- 66 Statistical Tests for Lateral Error and Flight Type at Look Ahead 1200 for Samples at All Altitudes**

Lon_Err By Type




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 2752 | -0.23783 | 10.3248 | 0.19681 |
| DEP | 2023 | 3.56685 | 11.4377 | 0.25430 |
| INR | 175 | 1.29445 | 6.4830 | 0.49007 |
| OVR | 8886 | 0.31763 | 7.2209 | 0.07660 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | DEP | INR | OVR | ARR |
|---|---|---|---|---|
| DEP | 0.00000 | 2.27240 | 3.24922 | 3.80467 |
| INR | -2.27240 | 0.00000 | 0.97682 | 1.53227 |
| OVR | -3.24922 | -0.97682 | 0.00000 | 0.55546 |
| ARR | -3.80467 | -1.53227 | -0.55546 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.56934

| Abs(Dif)-LSD | DEP | INR | OVR | ARR |
|---|---|---|---|---|
| DEP | -0.69658 | 0.52678 | 2.70347 | 3.15586 |
| INR | 0.52678 | -2.36837 | -0.71429 | -0.19485 |
| OVR | 2.70347 | -0.71429 | -0.33237 | 0.07216 |
| ARR | 3.15586 | -0.19485 | 0.07216 | -0.59723 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

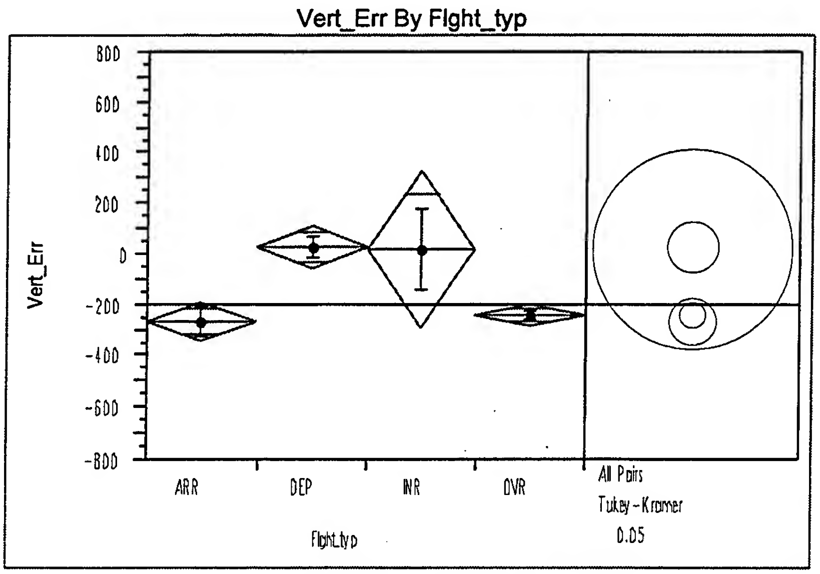
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 2752 | 10.32481 | 7.077953 | 7.042463 |
| DEP | 2023 | 11.43775 | 8.120808 | 8.061091 |
| INR | 175 | 6.48303 | 5.234365 | 5.063142 |
| OVR | 8886 | 7.22086 | 4.702144 | 4.701919 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 46.8839 | 3 | 13832 | <.0001 |
| Brown-Forsythe | 205.5680 | 3 | 13832 | <.0001 |
| Levene | 215.3588 | 3 | 13832 | <.0001 |
| Bartlett | 372.2710 | 3 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 55.8382 | 3 | 801.21 | <.0001 |

**Figure A.1- 67 Statistical Tests for Longitudinal Error and Flight Type at Look Ahead 1200 for Samples at All Altitudes**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 2752 | -266.505 | 3142.50 | 59.90 |
| DEP | 2023 | 32.538 | 1905.68 | 42.37 |
| INR | 175 | 19.197 | 2148.85 | 162.44 |
| OVR | 8886 | -237.760 | 1722.27 | 18.27 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | DEP | INR | OVR | ARR |
|---|---|---|---|---|
| DEP | 0.000 | 13.341 | 270.298 | 299.042 |
| INR | -13.341 | 0.000 | 256.957 | 285.701 |
| OVR | -270.298 | -256.957 | 0.000 | 28.745 |
| ARR | -299.042 | -285.701 | -28.745 | 0.000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.56934

| Abs(Dif)-LSD | DEP | INR | OVR | ARR |
|---|---|---|---|---|
| DEP | -170.580 | -414.131 | 136.653 | 140.160 |
| INR | -414.131 | -579.972 | -157.164 | -137.239 |
| OVR | 136.653 | -157.164 | -81.390 | -89.607 |
| ARR | 140.160 | -137.239 | -89.607 | -146.252 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 2752 | 3142.501 | 2192.247 | 2172.187 |
| DEP | 2023 | 1905.676 | 926.247 | 913.391 |
| INR | 175 | 2148.850 | 1385.400 | 1384.143 |
| OVR | 8886 | 1722.271 | 784.667 | 633.630 |

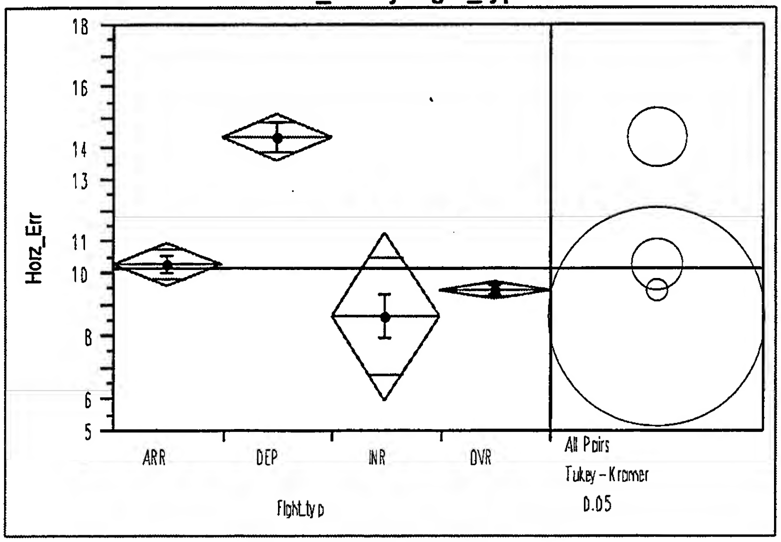
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 54.8177 | 3 | 13832 | <.0001 |
| Brown-Forsythe | 527.8600 | 3 | 13832 | 0.0000 |
| Levene | 478.1322 | 3 | 13832 | <.0001 |
| Bartlett | 613.3899 | 3 | ? | 0.0000 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 12.4580 | 3 | 791.61 | <.0001 |

**Figure A.1- 68 Statistical Tests for Vertical Error and Flight Type at Look Ahead 1200 for Samples at All Altitudes**

Horz_Err By Flght_typ




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 923 | 10.2990 | 10.3021 | 0.33910 |
| DEP | 774 | 14.3842 | 13.9167 | 0.50022 |
| INR | 61 | 8.6425 | 5.6802 | 0.72728 |
| OVR | 4686 | 9.4641 | 10.3259 | 0.15084 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | DEP | ARR | OVR | INR |
|---|---|---|---|---|
| DEP | 0.00000 | 4.08526 | 4.92009 | 5.74179 |
| ARR | -4.08526 | 0.00000 | 0.83483 | 1.65653 |
| OVR | -4.92009 | -0.83483 | 0.00000 | 0.82170 |
| INR | -5.74179 | -1.65653 | -0.82170 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.56970

| Abs(Dif)-LSD | DEP | ARR | OVR | INR |
|---|---|---|---|---|
| DEP | -1.40875 | 2.73456 | 3.84483 | 2.05627 |
| ARR | 2.73456 | -1.29004 | -0.16317 | -2.00719 |
| OVR | 3.84483 | -0.16317 | -0.57254 | -2.74966 |
| INR | 2.05627 | -2.00719 | -2.74966 | -5.01811 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 923 | 10.30205 | 7.13410 | 6.576544 |
| DEP | 774 | 13.91667 | 10.19334 | 9.676541 |
| INR | 61 | 5.68024 | 4.97916 | 4.921205 |
| OVR | 4686 | 10.32587 | 6.34870 | 5.914651 |

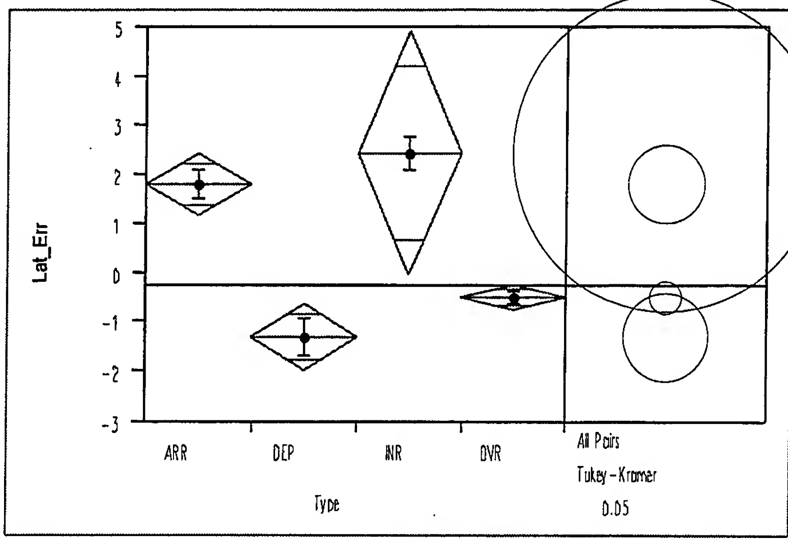
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 4.8899 | 3 | 6440 | 0.0021 |
| Brown-Forsythe | 38.7993 | 3 | 6440 | <.0001 |
| Levene | 50.2465 | 3 | 6440 | <.0001 |
| Bartlett | 58.0560 | 3 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 30.8836 | 3 | 285.23 | <.0001 |

**Figure A.1- 69 Statistical Tests for Horizontal Error and Flight Type at Look Ahead 1800 for Samples at All Altitudes**

Lat_Err By Type




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 923 | 1.84524 | 9.3618 | 0.30815 |
| DEP | 774 | -1.31193 | 10.6583 | 0.38310 |
| INR | 61 | 2.45212 | 2.8399 | 0.36361 |
| OVR | 4686 | -0.48365 | 10.0897 | 0.14739 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | INR | ARR | OVR | DEP |
|---|---|---|---|---|
| INR | 0.00000 | 0.60688 | 2.93577 | 3.76405 |
| ARR | -0.60688 | 0.00000 | 2.32889 | 3.15717 |
| OVR | -2.93577 | -2.32889 | 0.00000 | 0.82828 |
| DEP | -3.76405 | -3.15717 | -0.82828 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.56970

| Abs(Dif)-LSD | INR | ARR | OVR | DEP |
|---|---|---|---|---|
| INR | -4.66040 | -2.79567 | -0.38101 | 0.34126 |
| ARR | -2.79567 | -1.19808 | 1.40203 | 1.90275 |
| OVR | -0.38101 | 1.40203 | -0.53172 | -0.17033 |
| DEP | 0.34126 | 1.90275 | -0.17033 | -1.30833 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

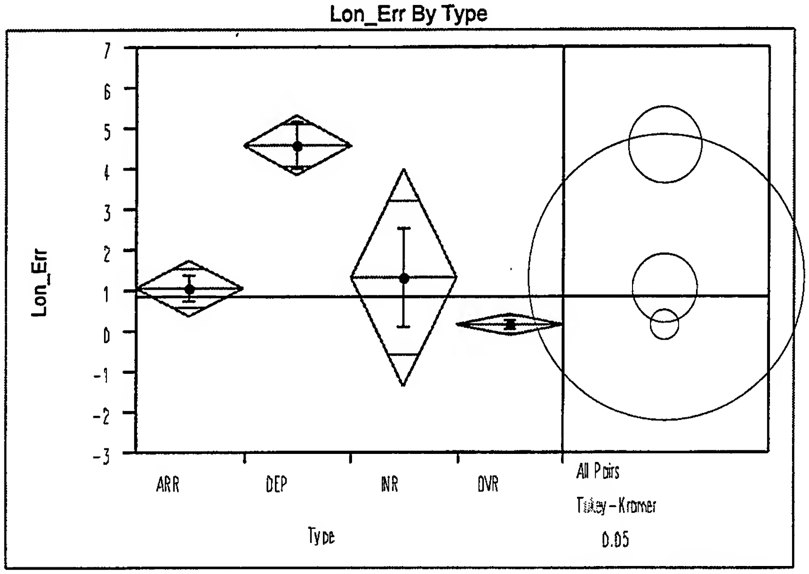
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 923 | 9.36175 | 5.056806 | 4.601354 |
| DEP | 774 | 10.65830 | 5.646032 | 5.238998 |
| INR | 61 | 2.83989 | 2.358812 | 2.014416 |
| OVR | 4686 | 10.08974 | 4.814552 | 4.715546 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 0.7704 | 3 | 6440 | 0.5104 |
| Brown-Forsythe | 2.8275 | 3 | 6440 | 0.0371 |
| Levene | 3.8527 | 3 | 6440 | 0.0091 |
| Bartlett | 36.8738 | 3 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 34.2560 | 3 | 329.56 | <.0001 |

**Figure A.1- 70 Statistical Tests for Lateral Error and Flight Type at Look Ahead 1800 for Samples at All Altitudes**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 923 | 1.08070 | 10.9588 | 0.3607 |
| DEP | 774 | 4.62673 | 16.2509 | 0.5841 |
| INR | 61 | 1.35041 | 9.6005 | 1.2292 |
| OVR | 4686 | 0.20939 | 9.7022 | 0.1417 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | DEP | INR | ARR | OVR |
|---|---|---|---|---|
| DEP | 0.00000 | 3.27632 | 3.54602 | 4.41734 |
| INR | -3.27632 | 0.00000 | 0.26970 | 1.14102 |
| ARR | -3.54602 | -0.26970 | 0.00000 | 0.87132 |
| OVR | -4.41734 | -1.14102 | -0.87132 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.56970

| Abs(Dif)-LSD | DEP | INR | ARR | OVR |
|---|---|---|---|---|
| DEP | -1.42034 | -0.43952 | 2.18420 | 3.33323 |
| INR | -0.43952 | -5.05940 | -3.42416 | -2.45973 |
| ARR | 2.18420 | -3.42416 | -1.30066 | -0.13490 |
| OVR | 3.33323 | -2.45973 | -0.13490 | -0.57725 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 923 | 10.95884 | 7.66131 | 7.65645 |
| DEP | 774 | 16.25086 | 11.28068 | 11.26191 |
| INR | 61 | 9.60051 | 7.87813 | 7.78761 |
| OVR | 4686 | 9.70217 | 6.60987 | 6.60351 |

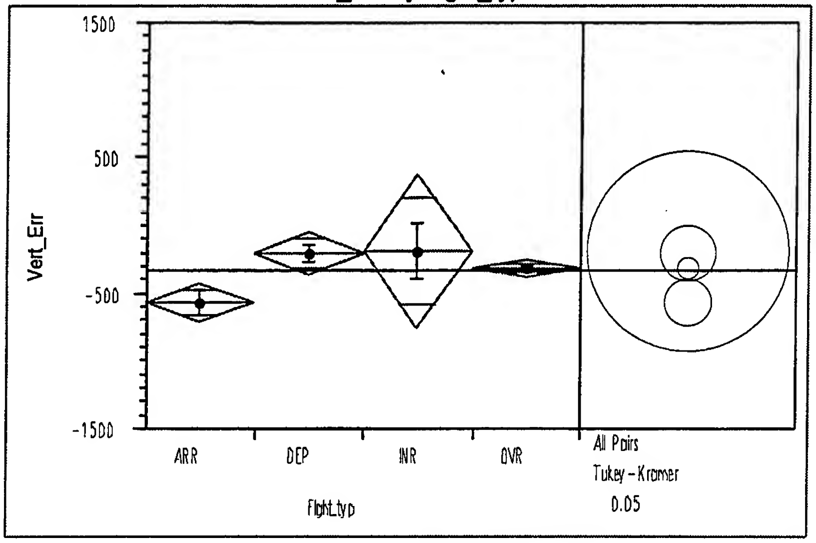
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 47.5172 | 3 | 6440 | <.0001 |
| Brown-Forsythe | 77.6498 | 3 | 6440 | <.0001 |
| Levene | 78.4720 | 3 | 6440 | <.0001 |
| Bartlett | 148.7540 | 3 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 18.9311 | 3 | 272.99 | <.0001 |

**Figure A.1- 71 Statistical Tests for Longitudinal Error and Flight Type at Look Ahead 1800 for Samples at All Altitudes**

Vert_Err By Flght_typ




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 923 | -554.826 | 3315.83 | 109.14 |
| DEP | 774 | -193.895 | 1909.90 | 68.65 |
| INR | 61 | -182.768 | 1606.16 | 205.65 |
| OVR | 4686 | -306.194 | 2109.86 | 30.82 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | INR | DEP | OVR | ARR |
|---|---|---|---|---|
| INR | 0.000 | 11.127 | 123.426 | 372.058 |
| DEP | -11.127 | 0.000 | 112.299 | 360.931 |
| OVR | -123.426 | -112.299 | 0.000 | 248.632 |
| ARR | -372.058 | -360.931 | -248.632 | 0.000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q*
2.56970

| Abs(Dif)-LSD | INR | DEP | OVR | ARR |
|---|---|---|---|---|
| INR | -1068.61 | -773.70 | -637.09 | -408.13 |
| DEP | -773.70 | -299.99 | -116.68 | 73.30 |
| OVR | -637.09 | -116.68 | -121.92 | 36.11 |
| ARR | -408.13 | 73.30 | 36.11 | -274.71 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 923 | 3315.832 | 2390.947 | 2384.889 |
| DEP | 774 | 1909.896 | 982.823 | 867.364 |
| INR | 61 | 1606.156 | 1124.436 | 1093.585 |
| OVR | 4686 | 2109.856 | 1060.170 | 882.069 |

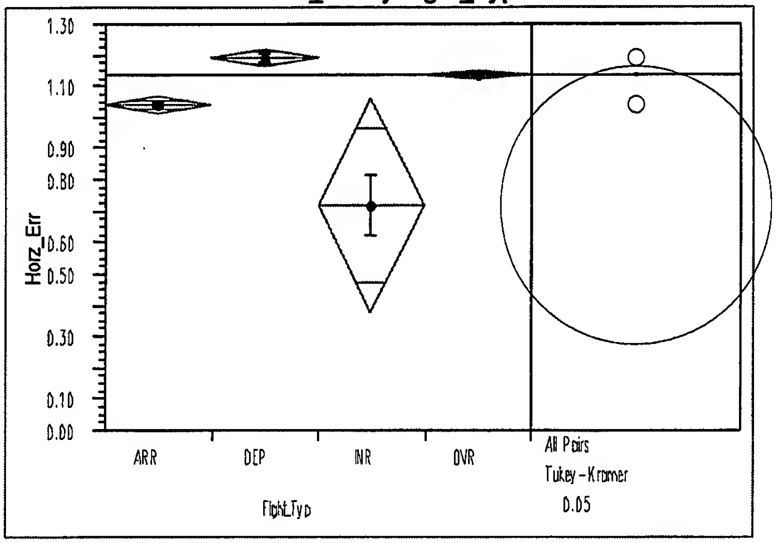
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 14.8573 | 3 | 6440 | <.0001 |
| Brown-Forsythe | 153.9664 | 3 | 6440 | <.0001 |
| Levene | 135.4751 | 3 | 6440 | <.0001 |
| Bartlett | 148.1365 | 3 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 2.7205 | 3 | 277.94 | 0.0448 |

**Figure A.1- 72 Statistical Tests for Vertical Error and Flight Type at Look Ahead 1800 for Samples at All Altitudes**

## Horz_Err By Fight_Typ




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 4349 | 1.04608 | 0.779149 | 0.01181 |
| DEP | 3954 | 1.19398 | 0.951797 | 0.01514 |
| INR | 28 | 0.72009 | 0.526729 | 0.09954 |
| OVR | 17817 | 1.14703 | 0.975480 | 0.00731 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | DEP | OVR | ARR | INR |
|---|---|---|---|---|
| DEP | 0.000000 | 0.046943 | 0.147892 | 0.473892 |
| OVR | -0.04694 | 0.000000 | 0.100950 | 0.426949 |
| ARR | -0.14789 | -0.10095 | 0.000000 | 0.325999 |
| INR | -0.47389 | -0.42695 | -0.326 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.56920

| Abs(Dif)-LSD | DEP | OVR | ARR | INR |
|---|---|---|---|---|
| DEP | -0.05441 | 0.004414 | 0.094733 | 0.015082 |
| OVR | 0.004414 | -0.02563 | 0.060032 | -0.0306 |
| ARR | 0.094733 | 0.060032 | -0.05188 | -0.13266 |
| INR | 0.015082 | -0.0306 | -0.13266 | -0.64657 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 4349 | 0.7791494 | 0.6031522 | 0.5858818 |
| DEP | 3954 | 0.9517968 | 0.6777382 | 0.6582575 |
| INR | 28 | 0.5267289 | 0.4490194 | 0.4421643 |
| OVR | 17817 | 0.9754801 | 0.6561249 | 0.6345357 |

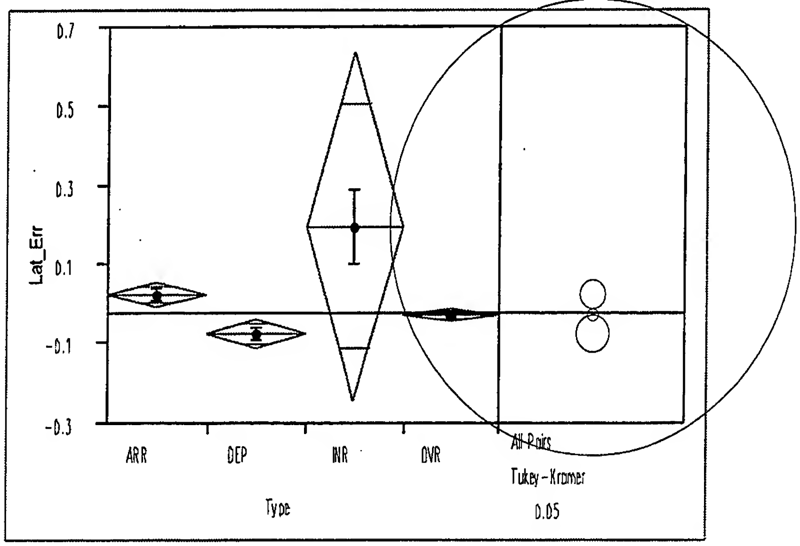
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 1.0137 | 3 | 26144 | 0.3853 |
| Brown-Forsythe | 8.1709 | 3 | 26144 | <.0001 |
| Levene | 10.3530 | 3 | 26144 | <.0001 |
| Bartlett | 111.3007 | 3 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 29.9164 | 3 | 134.7 | <.0001 |

**Figure A.1- 73 Statistical Tests for Horizontal Error and Flight Type at Look Ahead 0 for Samples at Altitudes Above 18,000 Feet**

Lat_Err By Type




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 4349 | 0.023929 | 1.08964 | 0.01652 |
| DEP | 3954 | -0.07542 | 1.20787 | 0.01921 |
| INR | 28 | 0.202157 | 0.52083 | 0.09843 |
| OVR | 17817 | -0.02599 | 1.22300 | 0.00916 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | INR | ARR | OVR | DEP |
|---|---|---|---|---|
| INR | 0.000000 | 0.178228 | 0.228142 | 0.277578 |
| ARR | -0.17823 | 0.000000 | 0.049914 | 0.099349 |
| OVR | -0.22814 | -0.04991 | 0.000000 | 0.049436 |
| DEP | -0.27758 | -0.09935 | -0.04944 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.56920

| Abs(Dif)-LSD | INR | ARR | OVR | DEP |
|---|---|---|---|---|
| INR | -0.82329 | -0.4058 | -0.35447 | -0.30663 |
| ARR | -0.4058 | -0.06606 | -0.00219 | 0.031660 |
| OVR | -0.35447 | -0.00219 | -0.03264 | -0.00472 |
| DEP | -0.30663 | 0.031660 | -0.00472 | -0.06928 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

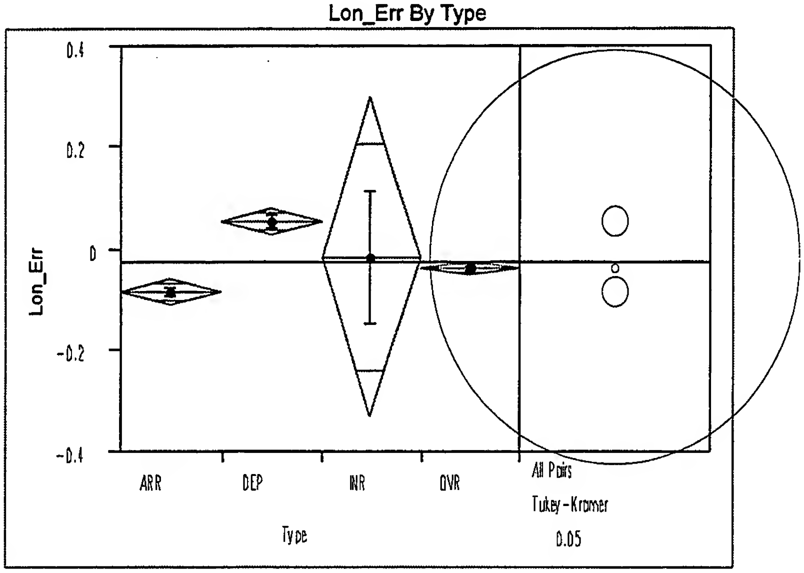
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 4349 | 1.089636 | 0.7363338 | 0.7355038 |
| DEP | 3954 | 1.207866 | 0.8603305 | 0.8572336 |
| INR | 28 | 0.520833 | 0.3176684 | 0.3121000 |
| OVR | 17817 | 1.222998 | 0.8094429 | 0.8089403 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 2.2692 | 3 | 26144 | 0.0783 |
| Brown-Forsythe | 16.3464 | 3 | 26144 | <.0001 |
| Levene | 16.7351 | 3 | 26144 | <.0001 |
| Bartlett | 37.3253 | 3 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 6.8777 | 3 | 135.28 | 0.0002 |

**Figure A.1- 74 Statistical Tests for Lateral Error and Flight Type at Look Ahead 0 for Samples at Altitudes Above 18,000 Feet**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 4349 | -0.07945 | 0.712339 | 0.01080 |
| DEP | 3954 | 0.064564 | 0.929010 | 0.01477 |
| INR | 28 | -0.00764 | 0.708145 | 0.13383 |
| OVR | 17817 | -0.03093 | 0.877478 | 0.00657 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | DEP | INR | OVR | ARR |
|---|---|---|---|---|
| DEP | 0.000000 | 0.072203 | 0.095493 | 0.144011 |
| INR | -0.0722 | 0.000000 | 0.023290 | 0.071808 |
| OVR | -0.09549 | -0.02329 | 0.000000 | 0.048519 |
| ARR | -0.14401 | -0.07181 | -0.04852 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.56920

| Abs(Dif)-LSD | DEP | INR | OVR | ARR |
|---|---|---|---|---|
| DEP | -0.04971 | -0.34697 | 0.056638 | 0.095444 |
| INR | -0.34697 | -0.59072 | -0.39474 | -0.34723 |
| OVR | 0.056638 | -0.39474 | -0.02342 | 0.011136 |
| ARR | 0.095444 | -0.34723 | 0.011136 | -0.0474 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

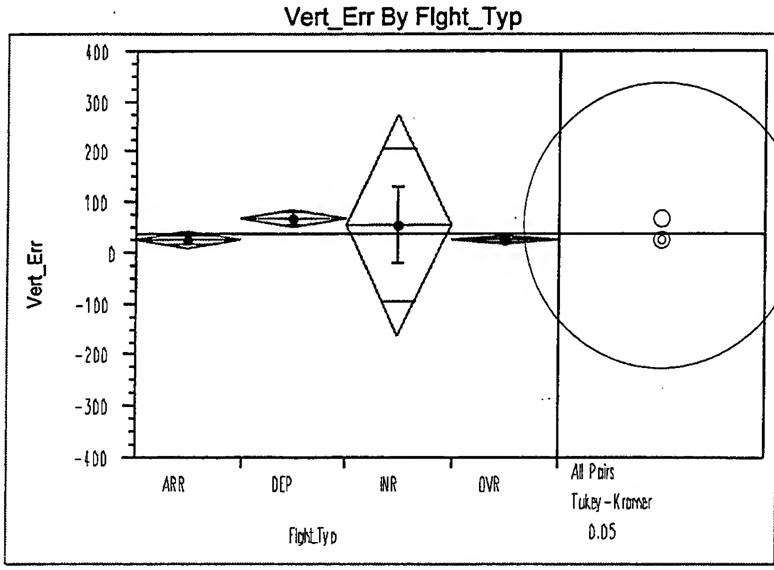
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 4349 | 0.7123388 | 0.5450016 | 0.5447454 |
| DEP | 3954 | 0.9290096 | 0.6044064 | 0.6039326 |
| INR | 28 | 0.7081455 | 0.5404064 | 0.5390250 |
| OVR | 17817 | 0.8774782 | 0.5987171 | 0.5985922 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 2.3048 | 3 | 26144 | 0.0747 |
| Brown-Forsythe | 9.4190 | 3 | 26144 | <.0001 |
| Levene | 9.4162 | 3 | 26144 | <.0001 |
| Bartlett | 112.6175 | 3 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 20.4530 | 3 | 134.2 | <.0001 |

**Figure A.1- 75 Statistical Tests for Longitudinal Error and Flight Type at Look Ahead 0 for Samples at Altitudes Above 18,000 Feet**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 4349 | 33.5672 | 678.371 | 10.287 |
| DEP | 3954 | 73.3885 | 796.740 | 12.671 |
| INR | 28 | 65.9412 | 408.616 | 77.221 |
| OVR | 17817 | 32.3289 | 510.259 | 3.823 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | DEP | INR | ARR | OVR |
|---|---|---|---|---|
| DEP | 0.0000 | 7.4473 | 39.8213 | 41.0596 |
| INR | -7.4473 | 0.0000 | 32.3741 | 33.6123 |
| ARR | -39.8213 | -32.3741 | 0.0000 | 1.2383 |
| OVR | -41.0596 | -33.6123 | -1.2383 | 0.0000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.56920

| Abs(Dif)-LSD | DEP | INR | ARR | OVR |
|---|---|---|---|---|
| DEP | -34.190 | -280.860 | 6.417 | 14.335 |
| INR | -280.860 | -406.292 | -255.841 | -253.905 |
| ARR | 6.417 | -255.841 | -32.600 | -24.474 |
| OVR | 14.335 | -253.905 | -24.474 | -16.106 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

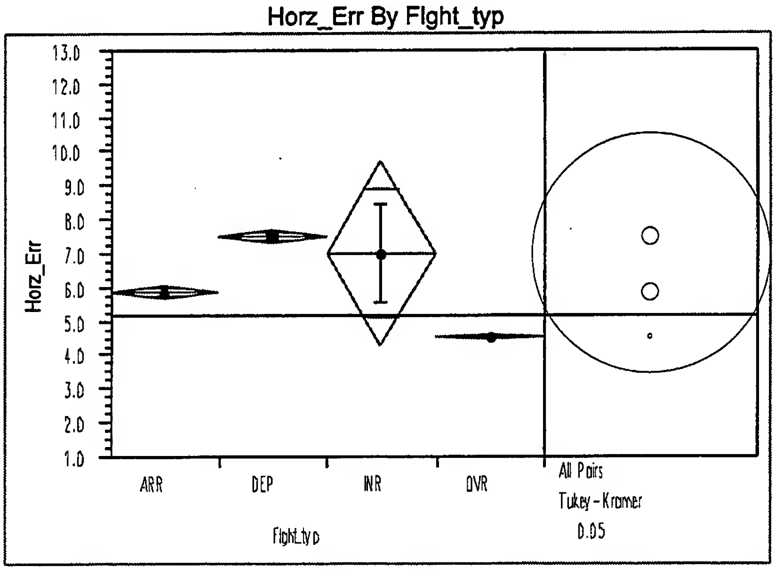
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 4349 | 678.3714 | 226.6330 | 210.8493 |
| DEP | 3954 | 796.7398 | 264.2650 | 232.0424 |
| INR | 28 | 408.6163 | 256.7743 | 226.6881 |
| OVR | 17817 | 510.2591 | 120.0023 | 97.5634 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 1.1109 | 3 | 26144 | 0.3432 |
| Brown-Forsythe | 88.3183 | 3 | 26144 | <.0001 |
| Levene | 94.5199 | 3 | 26144 | <.0001 |
| Bartlett | 582.8649 | 3 | ? | 0.0000 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 3.2411 | 3 | 134.08 | 0.0242 |

**Figure A.1- 76 Statistical Tests for Vertical Error and Flight Type at Look Ahead 0 for Samples at Altitudes Above 18,000 Feet**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 2180 | 5.86620 | 6.69565 | 0.1434 |
| DEP | 3140 | 7.50980 | 6.31770 | 0.1127 |
| INR | 16 | 7.05297 | 6.02153 | 1.5054 |
| OVR | 12874 | 4.55009 | 5.17903 | 0.0456 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | DEP | INR | ARR | OVR |
|---|---|---|---|---|
| DEP | 0.00000 | 0.45684 | 1.64360 | 2.95971 |
| INR | -0.45684 | 0.00000 | 1.18677 | 2.50287 |
| ARR | -1.64360 | -1.18677 | 0.00000 | 1.31610 |
| OVR | -2.95971 | -2.50287 | -1.31610 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.56927

| Abs(Dif)-LSD | DEP | INR | ARR | OVR |
|---|---|---|---|---|
| DEP | -0.36244 | -3.14254 | 1.24325 | 2.67388 |
| INR | -3.14254 | -5.07737 | -2.41662 | -1.08960 |
| ARR | 1.24325 | -2.41662 | -0.43498 | 0.98350 |
| OVR | 2.67388 | -1.08960 | 0.98350 | -0.17900 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

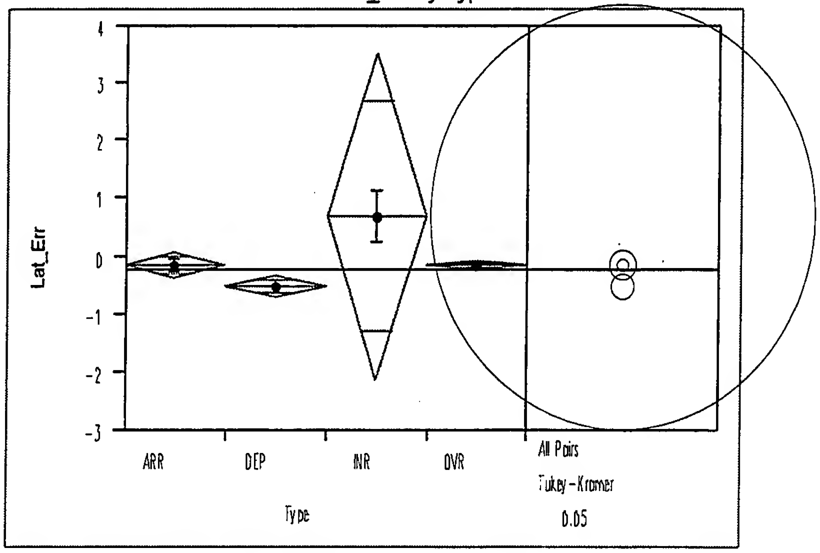
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 2180 | 6.695652 | 4.365687 | 3.987987 |
| DEP | 3140 | 6.317700 | 4.868264 | 4.673344 |
| INR | 16 | 6.021531 | 5.056123 | 4.711769 |
| OVR | 12874 | 5.179030 | 3.279434 | 2.983894 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 7.2002 | 3 | 18206 | <.0001 |
| Brown-Forsythe | 122.4661 | 3 | 18206 | <.0001 |
| Levene | 146.0102 | 3 | 18206 | <.0001 |
| Bartlett | 134.2650 | 3 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 206.3231 | 3 | 74.401 | <.0001 |

**Figure A.1- 77 Statistical Tests for Horizontal Error and Flight Type at Look Ahead 600 for Samples at Altitudes Above 18,000 Feet**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 2180 | -0.16896 | 6.26443 | 0.13417 |
| DEP | 3140 | -0.51797 | 6.36964 | 0.11367 |
| INR | 16 | 0.695931 | 1.85391 | 0.46348 |
| OVR | 12874 | -0.17524 | 5.59431 | 0.04930 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | INR | ARR | OVR | DEP |
|---|---|---|---|---|
| INR | 0.00000 | 0.86490 | 0.87117 | 1.21390 |
| ARR | -0.86490 | 0.00000 | 0.00628 | 0.34900 |
| OVR | -0.87117 | -0.00628 | 0.00000 | 0.34273 |
| DEP | -1.21390 | -0.34900 | -0.34273 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.56927

| Abs(Dif)-LSD | INR | ARR | OVR | DEP |
|---|---|---|---|---|
| INR | -5.28294 | -2.88439 | -2.86675 | -2.53121 |
| ARR | -2.88439 | -0.45259 | -0.33979 | -0.06756 |
| OVR | -2.86675 | -0.33979 | -0.18624 | 0.04532 |
| DEP | -2.53121 | -0.06756 | 0.04532 | -0.37711 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

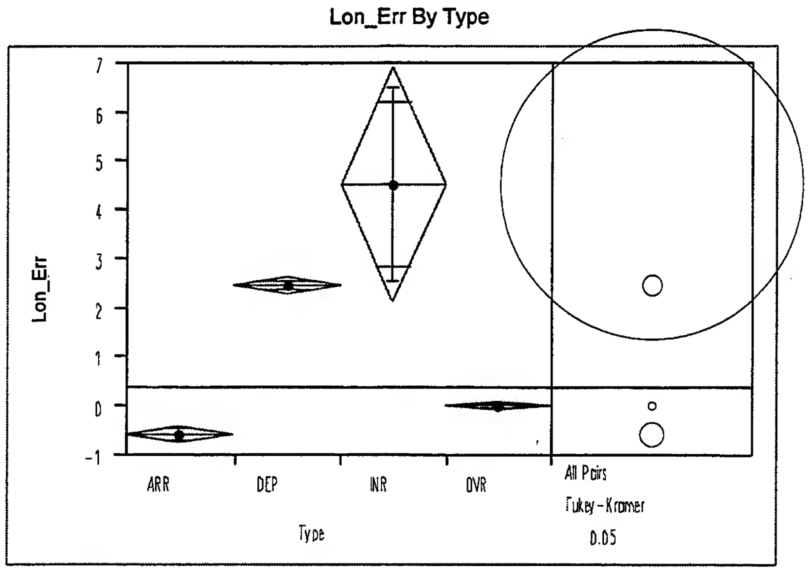
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 2180 | 6.264428 | 3.285577 | 3.271467 |
| DEP | 3140 | 6.369638 | 3.649050 | 3.564355 |
| INR | 16 | 1.853908 | 1.125722 | 0.959294 |
| OVR | 12874 | 5.594305 | 2.920873 | 2.901661 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 4.3455 | 3 | 18206 | 0.0046 |
| Brown-Forsythe | 17.5723 | 3 | 18206 | <.0001 |
| Levene | 20.5875 | 3 | 18206 | <.0001 |
| Bartlett | 46.0556 | 3 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 3.8437 | 3 | 75.584 | 0.0128 |

**Figure A.1- 78 Statistical Tests for Lateral Error and Flight Type at Look Ahead 600 for Samples at Altitudes Above 18,000 Feet**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 2180 | -0.54771 | 6.29985 | 0.1349 |
| DEP | 3140 | 2.49767 | 7.01765 | 0.1252 |
| INR | 16 | 4.58689 | 7.93243 | 1.9831 |
| OVR | 12874 | 0.04333 | 4.02473 | 0.0355 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | INR | DEP | OVR | ARR |
|---|---|---|---|---|
| INR | 0.00000 | 2.08922 | 4.54357 | 5.13460 |
| DEP | -2.08922 | 0.00000 | 2.45435 | 3.04538 |
| OVR | -4.54357 | -2.45435 | 0.00000 | 0.59103 |
| ARR | -5.13460 | -3.04538 | -0.59103 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.56927

| Abs(Dif)-LSD | INR | DEP | OVR | ARR |
|---|---|---|---|---|
| INR | -4.51878 | -1.11417 | 1.34632 | 1.92764 |
| DEP | -1.11417 | -0.32256 | 2.19996 | 2.68907 |
| OVR | 1.34632 | 2.19996 | -0.15930 | 0.29502 |
| ARR | 1.92764 | 2.68907 | 0.29502 | -0.38713 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

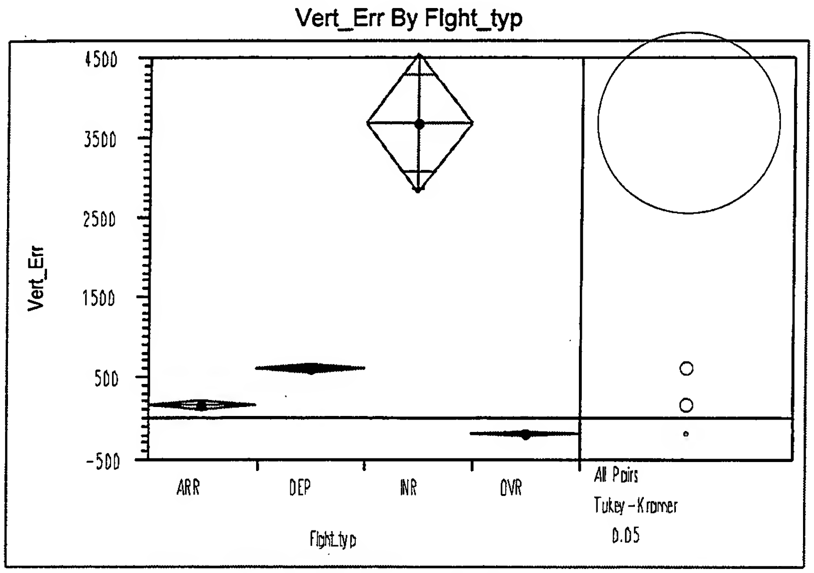
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 2180 | 6.299850 | 3.924904 | 3.888910 |
| DEP | 3140 | 7.017651 | 5.348000 | 5.294645 |
| INR | 16 | 7.932428 | 6.865618 | 6.553169 |
| OVR | 12874 | 4.024735 | 2.592419 | 2.592157 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 60.2987 | 3 | 18206 | <.0001 |
| Brown-Forsythe | 487.4840 | 3 | 18206 | <.0001 |
| Levene | 520.7569 | 3 | 18206 | 0.0000 |
| Bartlett | 744.9788 | 3 | ? | 0.0000 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 128.1541 | 3 | 74.281 | <.0001 |

**Figure A.1- 79 Statistical Tests for Longitudinal Error and Flight Type at Look Ahead 600 for Samples at Altitudes Above 18,000 Feet**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 2180 | 175.38 | 2729.41 | 58.46 |
| DEP | 3140 | 627.24 | 2684.06 | 47.90 |
| INR | 16 | 3707.17 | 3264.89 | 816.22 |
| OVR | 12874 | -168.77 | 1227.70 | 10.82 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | INR | DEP | ARR | OVR |
|---|---|---|---|---|
| INR | 0.00 | 3079.93 | 3531.79 | 3875.94 |
| DEP | -3079.93 | 0.00 | 451.86 | 796.01 |
| ARR | -3531.79 | -451.86 | 0.00 | 344.15 |
| OVR | -3875.94 | -796.01 | -344.15 | 0.00 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.56927

| Abs(Dif)-LSD | INR | DEP | ARR | OVR |
|---|---|---|---|---|
| INR | -1627.04 | 1926.51 | 2377.09 | 2724.73 |
| DEP | 1926.51 | -116.14 | 323.57 | 704.42 |
| ARR | 2377.09 | 323.57 | -139.39 | 237.57 |
| OVR | 2724.73 | 704.42 | 237.57 | -57.36 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

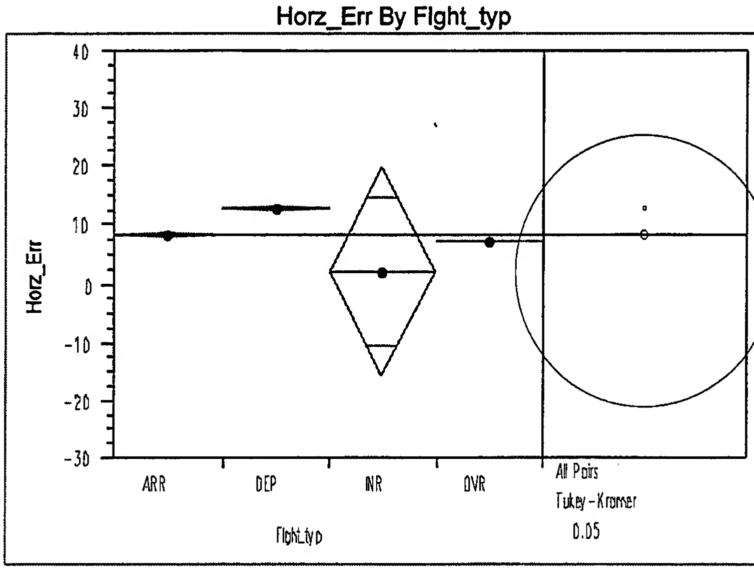
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 2180 | 2729.411 | 1761.558 | 1703.610 |
| DEP | 3140 | 2684.064 | 1748.244 | 1525.927 |
| INR | 16 | 3264.890 | 2778.220 | 2778.220 |
| OVR | 12874 | 1227.696 | 543.385 | 426.297 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 230.5318 | 3 | 18206 | <.0001 |
| Brown-Forsythe | 728.5862 | 3 | 18206 | 0.0000 |
| Levene | 886.8506 | 3 | 18206 | 0.0000 |
| Bartlett | 1764.0818 | 3 | ? | 0.0000 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 101.9032 | 3 | 74.222 | <.0001 |

**Figure A.1- 80 Statistical Tests for Vertical Error and Flight Type at Look Ahead 600 for Samples at Altitudes Above 18,000 Feet**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 729 | 8.7146 | 10.0791 | 0.37330 |
| DEP | 1365 | 13.4251 | 11.2510 | 0.30452 |
| INR | 1 | 2.4478 | ? | ? |
| OVR | 8279 | 7.6036 | 8.6140 | 0.09467 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | DEP | ARR | OVR | INR |
|---|---|---|---|---|
| DEP | 0.0000 | 4.7105 | 5.8215 | 10.9773 |
| ARR | -4.7105 | 0.0000 | 1.1110 | 6.2668 |
| OVR | -5.8215 | -1.1110 | 0.0000 | 5.1558 |
| INR | -10.9773 | -6.2668 | -5.1558 | 0.0000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.56945

| Abs(Dif)-LSD | DEP | ARR | OVR | INR |
|---|---|---|---|---|
| DEP | -0.8961 | 3.6366 | 5.1376 | -12.4419 |
| ARR | 3.6366 | -1.2262 | 0.2066 | -17.1599 |
| OVR | 5.1376 | 0.2066 | -0.3639 | -18.2563 |
| INR | -12.4419 | -17.1599 | -18.2563 | -33.1077 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 729 | 10.07914 | 6.567019 | 6.022739 |
| DEP | 1365 | 11.25095 | 8.540999 | 8.215322 |
| INR | 1 | ? | 0.000000 | 0.000000 |
| OVR | 8279 | 8.61395 | 5.298427 | 4.889349 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 5.2489 | 2 | 10370 | 0.0053 |
| Brown-Forsythe | 112.7594 | 2 | 10370 | <.0001 |
| Levene | 133.0604 | 2 | 10370 | <.0001 |
| Bartlett | 103.2482 | 2 | ? | <.0001 |

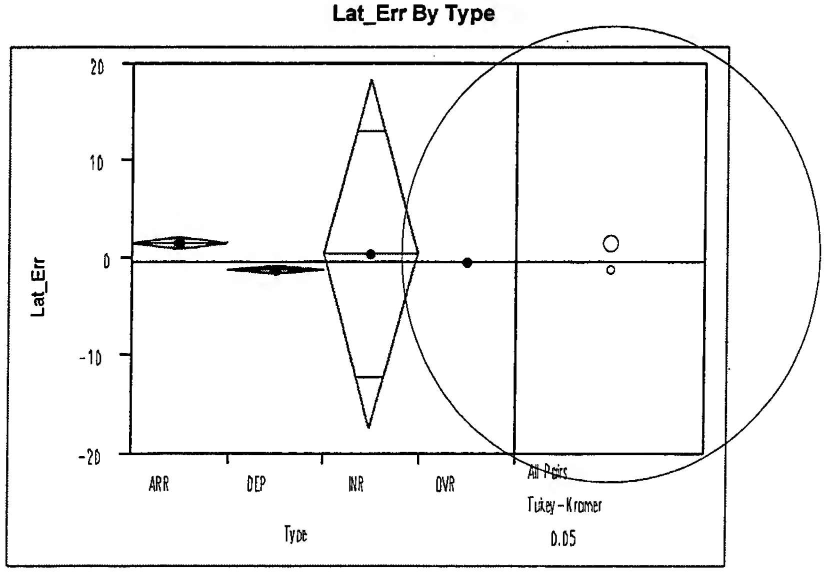
Warning: Small sample sizes. Use Caution.

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 167.7543 | 2 | 1446 | <.0001 |

**Figure A.1- 81 Statistical Tests for Horizontal Error and Flight Type at Look Ahead 1200 for Samples at Altitudes Above 18,000 Feet**

**Lat_Err By Type**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 729 | 1.56100 | 8.4561 | 0.31319 |
| DEP | 1365 | -1.20794 | 11.3769 | 0.30793 |
| INR | 1 | 0.44280 | ? | ? |
| OVR | 8279 | -0.27068 | 8.8052 | 0.09677 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | ARR | INR | OVR | DEP |
|---|---|---|---|---|
| ARR | 0.00000 | 1.11820 | 1.83168 | 2.76894 |
| INR | -1.11820 | 0.00000 | 0.71348 | 1.65074 |
| OVR | -1.83168 | -0.71348 | 0.00000 | 0.93726 |
| DEP | -2.76894 | -1.65074 | -0.93726 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.56945

| Abs(Dif)-LSD | ARR | INR | OVR | DEP |
|---|---|---|---|---|
| ARR | -1.2330 | -22.4383 | 0.9222 | 1.6891 |
| INR | -22.4383 | -33.2911 | -22.8283 | -21.8982 |
| OVR | 0.9222 | -22.8283 | -0.3659 | 0.2496 |
| DEP | 1.6891 | -21.8982 | 0.2496 | -0.9011 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 729 | 8.45614 | 4.767762 | 4.416341 |
| DEP | 1365 | 11.37686 | 6.363812 | 6.059668 |
| INR | 1 | ? | 0.000000 | 0.000000 |
| OVR | 8279 | 8.80522 | 4.409537 | 4.367785 |

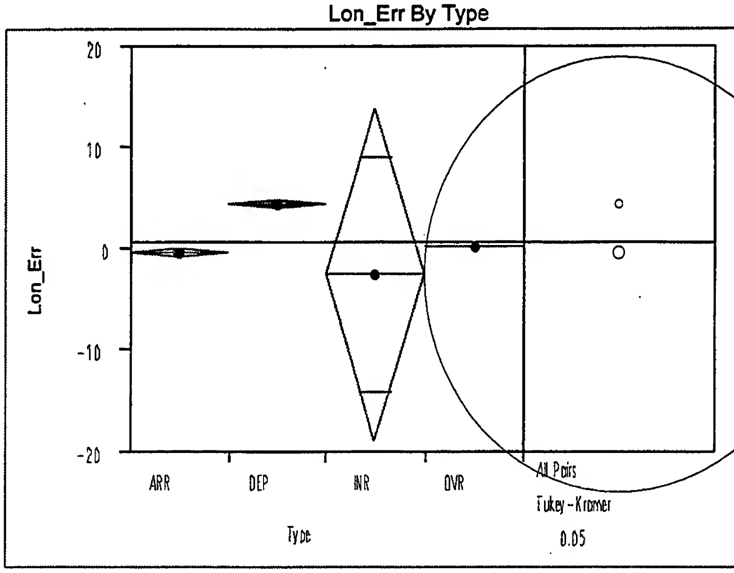
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 7.8126 | 2 | 10370 | 0.0004 |
| Brown-Forsythe | 26.8696 | 2 | 10370 | <.0001 |
| Levene | 36.4313 | 2 | 10370 | <.0001 |
| Bartlett | 91.3932 | 2 | ? | <.0001 |

Warning: Small sample sizes. Use Caution.

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 21.4219 | 2 | 1495.7 | <.0001 |

**Figure A.1- 82 Statistical Tests for Lateral Error and Flight Type at Look Ahead 1200 for Samples at Altitudes Above 18,000 Feet**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 729 | -0.38947 | 10.1754 | 0.37687 |
| DEP | 1365 | 4.47971 | 12.4889 | 0.33803 |
| INR | 1 | -2.40740 | ? | ? |
| OVR | 8279 | 0.29626 | 7.3708 | 0.08101 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | DEP | OVR | ARR | INR |
|---|---|---|---|---|
| DEP | 0.00000 | 4.18344 | 4.86918 | 6.88711 |
| OVR | -4.18344 | 0.00000 | 0.68573 | 2.70366 |
| ARR | -4.86918 | -0.68573 | 0.00000 | 2.01793 |
| INR | -6.88711 | -2.70366 | -2.01793 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.56945

| Abs(Dif)-LSD | DEP | OVR | ARR | INR |
|---|---|---|---|---|
| DEP | -0.8296 | 3.5503 | 3.8749 | -14.7947 |
| OVR | 3.5503 | -0.3369 | -0.1516 | -18.9715 |
| ARR | 3.8749 | -0.1516 | -1.1352 | -19.6708 |
| INR | -14.7947 | -18.9715 | -19.6708 | -30.6515 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 729 | 10.17541 | 6.081124 | 6.059737 |
| DEP | 1365 | 12.48892 | 9.400217 | 9.368357 |
| INR | 1 | ? | 0.000000 | 0.000000 |
| OVR | 8279 | 7.37080 | 4.808462 | 4.808404 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 57.1117 | 2 | 10370 | <.0001 |
| Brown-Forsythe | 317.8020 | 2 | 10370 | <.0001 |
| Levene | 324.5898 | 2 | 10370 | <.0001 |
| Bartlett | 444.6502 | 2 | ? | <.0001 |

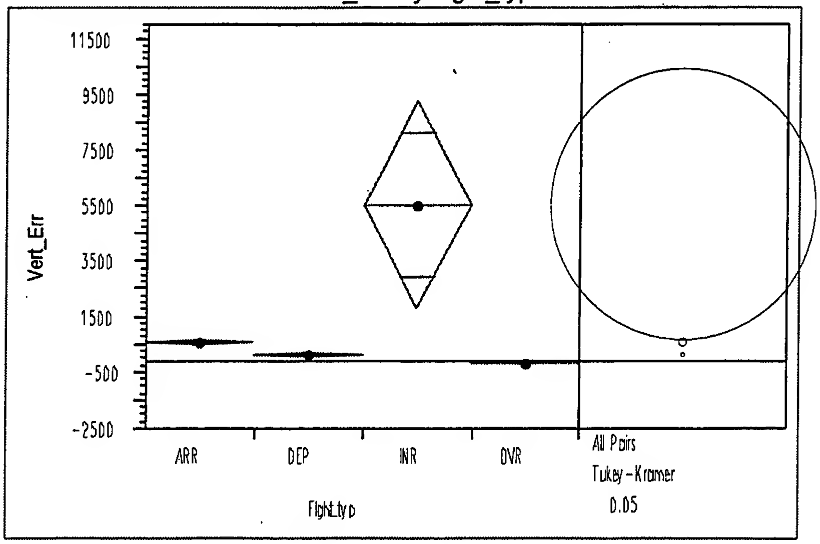
Warning: Small sample sizes. Use Caution.

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 75.1969 | 2 | 1388.2 | <.0001 |

**Figure A.1- 83 Statistical Tests for Longitudinal Error and Flight Type at Look Ahead 1200 for Samples at Altitudes Above 18,000 Feet**

Vert_Err By Flght_typ




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 729 | 579.37 | 3291.49 | 121.91 |
| DEP | 1365 | 104.24 | 2134.86 | 57.78 |
| INR | 1 | 5507.95 | ? | ? |
| OVR | 8279 | -198.02 | 1698.40 | 18.67 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | INR | ARR | DEP | OVR |
|---|---|---|---|---|
| INR | 0.00 | 4928.58 | 5403.71 | 5705.97 |
| ARR | -4928.58 | 0.00 | 475.12 | 777.39 |
| DEP | -5403.71 | -475.12 | 0.00 | 302.26 |
| OVR | -5705.97 | -777.39 | -302.26 | 0.00 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.56945

| Abs(Dif)-LSD | INR | ARR | DEP | OVR |
|---|---|---|---|---|
| INR | -6954.32 | 7.76 | 484.46 | 788.23 |
| ARR | 7.76 | -257.57 | 249.54 | 587.41 |
| DEP | 484.46 | 249.54 | -188.23 | 158.61 |
| OVR | 788.23 | 587.41 | 158.61 | -76.43 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 729 | 3291.494 | 2276.198 | 2138.758 |
| DEP | 1365 | 2134.857 | 1136.639 | 1086.583 |
| INR | 1 | ? | 0.000 | 0.000 |
| OVR | 8279 | 1698.399 | 733.179 | 605.093 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 29.8563 | 2 | 10370 | <.0001 |
| Brown-Forsythe | 292.7935 | 2 | 10370 | <.0001 |
| Levene | 312.5342 | 2 | 10370 | <.0001 |
| Bartlett | 444.4994 | 2 | ? | <.0001 |

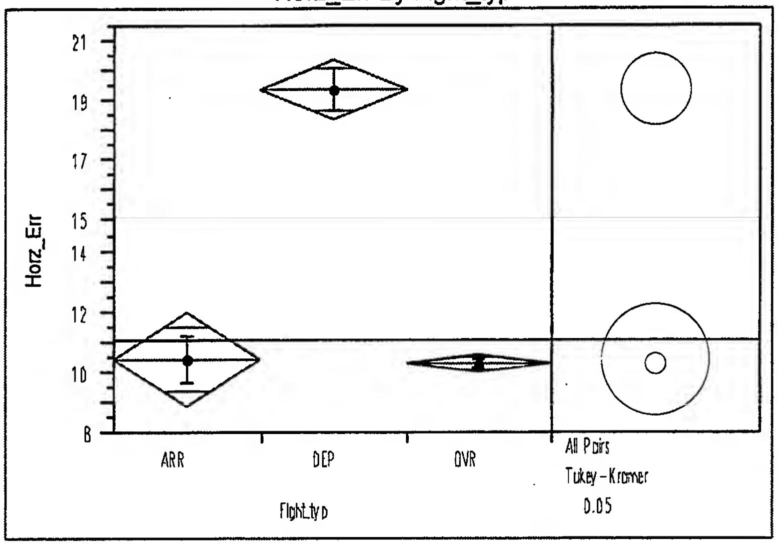
Warning: Small sample sizes. Use Caution.

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 30.8476 | 2 | 1387.2 | <.0001 |

**Figure A.1- 84 Statistical Tests for Vertical Error and Flight Type at Look Ahead 1200 for Samples at Altitudes Above 18,000 Feet**

Horz_Err By Flght_typ




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 192 | 9.8864 | 11.3504 | 0.81914 |
| DEP | 453 | 18.8873 | 15.5140 | 0.72891 |
| OVR | 4246 | 9.7690 | 10.6856 | 0.16399 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | DEP | ARR | OVR |
|---|---|---|---|
| DEP | 0.00000 | 9.00087 | 9.11827 |
| ARR | -9.00087 | 0.00000 | 0.11739 |
| OVR | -9.11827 | -0.11739 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34442

| Abs(Dif)-LSD | DEP | ARR | OVR |
|---|---|---|---|
| DEP | -1.75171 | 6.73060 | 7.81522 |
| ARR | 6.73060 | -2.69068 | -1.82775 |
| OVR | 7.81522 | -1.82775 | -0.57217 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 192 | 11.35035 | 7.21880 | 6.58526 |
| DEP | 453 | 15.51400 | 11.54072 | 11.16352 |
| OVR | 4246 | 10.68558 | 6.58978 | 6.13299 |

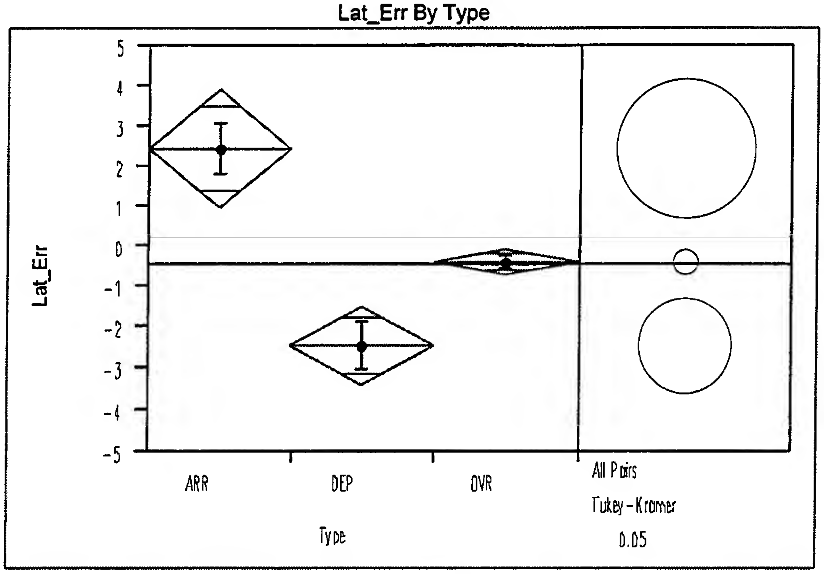
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 6.9458 | 2 | 4888 | 0.0010 |
| Brown-Forsythe | 58.2217 | 2 | 4888 | <.0001 |
| Levene | 67.5119 | 2 | 4888 | <.0001 |
| Bartlett | 69.3221 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 74.4201 | 2 | 388.08 | <.0001 |

**Figure A.1- 85 Statistical Tests for Horizontal Error and Flight Type at Look Ahead 1800 for Samples at Altitudes Above 18,000 Feet**

Lat_Err By Type




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 192 | 2.45824 | 9.2059 | 0.66438 |
| DEP | 453 | -2.41967 | 13.2625 | 0.62313 |
| OVR | 4246 | -0.36431 | 10.4774 | 0.16079 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | ARR | OVR | DEP |
|---|---|---|---|
| ARR | 0.00000 | 2.82254 | 4.87791 |
| OVR | -2.82254 | 0.00000 | 2.05537 |
| DEP | -4.87791 | -2.05537 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34442

| Abs(Dif)-LSD | ARR | OVR | DEP |
|---|---|---|---|
| ARR | -2.56497 | 0.96828 | 2.71371 |
| OVR | 0.96828 | -0.54543 | 0.81320 |
| DEP | 2.71371 | 0.81320 | -1.66987 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 192 | 9.20588 | 5.485769 | 4.839015 |
| DEP | 453 | 13.26254 | 7.757803 | 7.047101 |
| OVR | 4246 | 10.47740 | 4.954473 | 4.880312 |

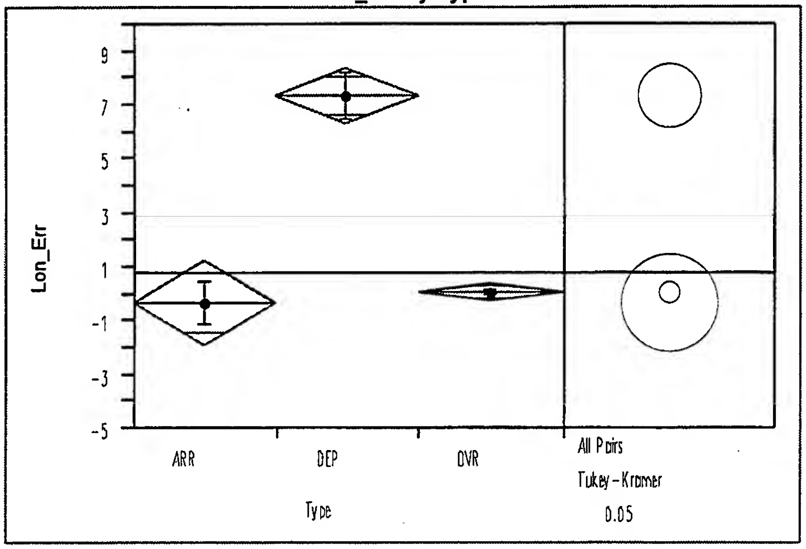
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 2.2232 | 2 | 4888 | 0.1084 |
| Brown-Forsythe | 10.7965 | 2 | 4888 | <.0001 |
| Levene | 18.5959 | 2 | 4888 | <.0001 |
| Bartlett | 29.8818 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 14.4264 | 2 | 400.05 | <.0001 |

**Figure A.1- 86 Statistical Tests for Lateral Error and Flight Type at Look Ahead 1800 for Samples at Altitudes Above 18,000 Feet**

Lon_Err By Type




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 192 | -0.28145 | 11.6697 | 0.84218 |
| DEP | 453 | 7.35761 | 19.0312 | 0.89416 |
| OVR | 4246 | 0.12236 | 9.9857 | 0.15325 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | DEP | OVR | ARR |
|---|---|---|---|
| DEP | 0.00000 | 7.23525 | 7.63906 |
| OVR | -7.23525 | 0.00000 | 0.40382 |
| ARR | -7.63906 | -0.40382 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34442

| Abs(Dif)-LSD | DEP | OVR | ARR |
|---|---|---|---|
| DEP | -1.74448 | 5.93757 | 5.37816 |
| OVR | 5.93757 | -0.56980 | -1.53329 |
| ARR | 5.37816 | -1.53329 | -2.67957 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 192 | 11.66965 | 6.81430 | 6.80113 |
| DEP | 453 | 19.03118 | 13.86243 | 13.85707 |
| OVR | 4246 | 9.98569 | 6.81711 | 6.81249 |

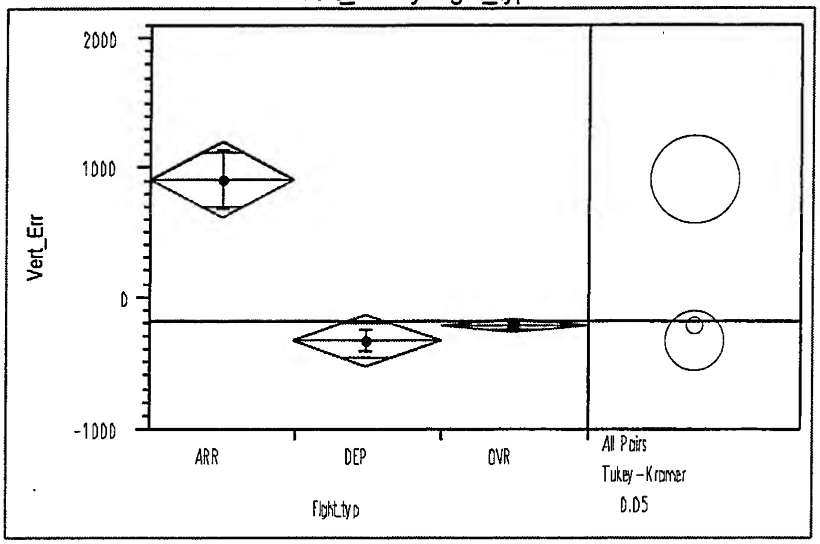
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 86.6965 | 2 | 4888 | <.0001 |
| Brown-Forsythe | 155.5814 | 2 | 4888 | <.0001 |
| Levene | 155.9712 | 2 | 4888 | <.0001 |
| Bartlett | 238.7980 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 32.0015 | 2 | 380.57 | <.0001 |

**Figure A.1- 87 Statistical Tests for Longitudinal Error and Flight Type at Look Ahead 1800 for Samples at Altitudes Above 18,000 Feet**

Vert_Err By Flght_typ




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 192 | 915.073 | 3306.58 | 238.63 |
| DEP | 453 | -325.001 | 2054.36 | 96.52 |
| OVR | 4246 | -214.247 | 2071.27 | 31.79 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | ARR | OVR | DEP |
|---|---|---|---|
| ARR | 0.00 | 1129.32 | 1240.07 |
| OVR | -1129.32 | 0.00 | 110.75 |
| DEP | -1240.07 | -110.75 | 0.00 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q*
2.34442

| Abs(Dif)-LSD | ARR | OVR | DEP |
|---|---|---|---|
| ARR | -510.016 | 760.620 | 809.745 |
| OVR | 760.620 | -108.454 | -136.239 |
| DEP | 809.745 | -136.239 | -332.036 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 192 | 3306.584 | 2495.533 | 2281.024 |
| DEP | 453 | 2054.355 | 1156.018 | 964.542 |
| OVR | 4246 | 2071.266 | 952.880 | 823.117 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 4.2822 | 2 | 4888 | 0.0139 |
| Brown-Forsythe | 52.4411 | 2 | 4888 | <.0001 |
| Levene | 65.6802 | 2 | 4888 | <.0001 |
| Bartlett | 54.4102 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 11.8078 | 2 | 387.5 | <.0001 |

**Figure A.1- 88 Statistical Tests for Vertical Error and Flight Type at Look Ahead 1800 for Samples at Altitudes Above 18,000 Feet**

## *A.1.3 Horizontal Phase of Flight per Look Ahead Time*

### A.1.3.1 Summary Tables

| Look Ahead Time | 0 | | 300 | |
|---|---|---|---|---|
| Horizontal Phase of Flight | Straight | Turn | Straight | Turn |
| Sample Quantity | 30644 | 5284 | 25710 | 4089 |
| Avg. Horz. Error | 1.19 | 1.29 | 3.16 | 3.17 |
| Stddev. Horz. Error | 1.05 | 1.27 | 3.38 | 3.53 |
| Max. Horz. Error | 42.39 | 16.91 | 84.31 | 65.56 |
| Min. Horz. Error | 0 | 0 | 0.01 | 0.03 |
| Avg. Lat. Error | -0.02 | -0.03 | -0.11 | -0.02 |
| Stddev. Lat. Error | 1.31 | 1.54 | 3.65 | 3.6 |
| Max. Lat. Error | 32.23 | 13.48 | 65.49 | 24.97 |
| Min. Lat. Error | -12.79 | -16 | -39.47 | -36.73 |
| Avg. Abs. Lat. Error | 0.86 | 0.96 | 1.98 | 1.98 |
| Stddev. Abs. Lat. Error | 0.99 | 1.2 | 3.07 | 3 |
| Max. Abs. Lat. Error | 32.23 | 16 | 65.49 | 36.73 |
| Min. Abs. Lat. Error | 0 | 0 | 0 | 0 |
| Avg. Long. Error | -0.01 | -0.06 | 0.12 | -0.11 |
| Stddev. Long. Error | 0.9 | 0.95 | 2.84 | 3.09 |
| Max. Long. Error | 11.93 | 9.33 | 25.52 | 22.3 |
| Min. Long. Error | -27.53 | -9.81 | -63.13 | -65.39 |
| Avg. Abs. Long. Error | 0.6 | 0.64 | 1.87 | 1.92 |
| Stddev. Abs. Long. Error | 0.67 | 0.71 | 2.13 | 2.41 |
| Max. Abs. Long. Error | 27.53 | 9.81 | 63.13 | 65.39 |
| Min. Abs. Long. Error | 0 | 0 | 0 | 0 |
| Avg. Vert. Error | 47.19 | 61.93 | -5.09 | -18.64 |
| Stddev. Vert. Error | 649.95 | 733.67 | 1611.37 | 1623.68 |
| Max. Vert. Error | 36817 | 21071.71 | 34817 | 9649 |
| Min. Vert. Error | -6824.15 | -4734 | -12626.9 | -12244.5 |
| Avg. Abs. Vert. Error | 193.1 | 268.05 | 726.83 | 788.28 |
| Stddev. Abs. Vert. Error | 622.39 | 685.74 | 1438.14 | 1419.56 |
| Max. Abs. Vert. Error | 36817 | 21071.71 | 34817 | 12244.45 |
| Min. Abs. Vert. Error | 0 | 0 | 0 | 0 |
| Avg. Slant Range Error | 1.19 | 1.3 | 3.18 | 3.18 |
| Stddev. Slant Range Error | 1.05 | 1.27 | 3.37 | 3.52 |
| Max. Slant Range Error | 42.39 | 16.91 | 84.34 | 65.56 |
| Min. Slant Range Error | 0 | 0 | 0.01 | 0.04 |

**Figure A.1- 89 Descriptive Statistics for Horizontal Phase of Flight per Look Ahead Time for Samples at All Altitudes**

| Look Ahead Time | 600 | | 900 | |
|---|---|---|---|---|
| Horizontal Phase of Flight | Straight | Turn | Straight | Turn |
| Sample Quantity | 20696 | 3268 | 15904 | 2625 |
| Avg. Horz. Error | 5.16 | 4.81 | 6.88 | 6.48 |
| Stddev. Horz. Error | 5.49 | 5.3 | 7.32 | 7.05 |
| Max. Horz. Error | 125.68 | 92.46 | 167.79 | 150.3 |
| Min. Horz. Error | 0.02 | 0.03 | 0.02 | 0.05 |
| Avg. Lat. Error | -0.19 | -0.05 | -0.23 | -0.15 |
| Stddev. Lat. Error | 5.49 | 5.05 | 7.07 | 6.42 |
| Max. Lat. Error | 97.45 | 71.88 | 129.48 | 115.83 |
| Min. Lat. Error | -61.74 | -53.06 | -94.55 | -59.15 |
| Avg. Abs. Lat. Error | 2.9 | 2.61 | 3.66 | 3.19 |
| Stddev. Abs. Lat. Error | 4.66 | 4.32 | 6.05 | 5.57 |
| Max. Abs. Lat. Error | 97.45 | 71.88 | 129.48 | 115.83 |
| Min. Abs. Lat. Error | 0 | 0 | 0 | 0 |
| Avg. Long. Error | 0.44 | -0.14 | 0.59 | 0.11 |
| Stddev. Long. Error | 5.13 | 5.06 | 7.11 | 7.1 |
| Max. Long. Error | 91.73 | 67.54 | 94.25 | 41.71 |
| Min. Long. Error | -79.36 | -58.15 | -106.71 | -95.77 |
| Avg. Abs. Long. Error | 3.31 | 3.27 | 4.59 | 4.64 |
| Stddev. Abs. Long. Error | 3.95 | 3.87 | 5.45 | 5.37 |
| Max. Abs. Long. Error | 91.73 | 67.54 | 106.71 | 95.77 |
| Min. Abs. Long. Error | 0 | 0 | 0 | 0 |
| Avg. Vert. Error | -118 | -180.93 | -180.03 | -204.44 |
| Stddev. Vert. Error | 1956.29 | 1989.43 | 2003.17 | 2027.8 |
| Max. Vert. Error | 28933 | 14957.77 | 30746.5 | 25785.61 |
| Min. Vert. Error | -15373.8 | -12081.6 | -16419.3 | -14157.8 |
| Avg. Abs. Vert. Error | 908.33 | 978.49 | 932.57 | 1025.48 |
| Stddev. Abs. Vert. Error | 1736.63 | 1741.51 | 1781.95 | 1761.19 |
| Max. Abs. Vert. Error | 28933 | 14957.77 | 30746.5 | 25785.61 |
| Min. Abs. Vert. Error | 0 | 0 | 0 | 0 |
| Avg. Slant Range Error | 5.17 | 4.82 | 6.89 | 6.5 |
| Stddev. Slant Range Error | 5.49 | 5.29 | 7.31 | 7.04 |
| Max. Slant Range Error | 125.72 | 92.49 | 167.86 | 150.36 |
| Min. Slant Range Error | 0.02 | 0.03 | 0.03 | 0.05 |

**Figure A.1- 90 Descriptive Statistics for Horizontal Phase of Flight per Look Ahead Time for Samples at All Altitudes**

| Look Ahead Time | 1200 | | 1500 | |
|---|---|---|---|---|
| Horizontal Phase of Flight | Straight | Turn | Straight | Turn |
| Sample Quantity | 11777 | 2059 | 8172 | 1506 |
| Avg. Horz. Error | 8.36 | 7.62 | 9.47 | 8.78 |
| Stddev. Horz. Error | 9.08 | 7.68 | 10.29 | 8.93 |
| Max. Horz. Error | 173.62 | 59.78 | 156.35 | 75.02 |
| Min. Horz. Error | 0.02 | 0.05 | 0.01 | 0.09 |
| Avg. Lat. Error | -0.19 | -0.35 | -0.25 | -0.2 |
| Stddev. Lat. Error | 8.7 | 6.49 | 9.8 | 7.6 |
| Max. Lat. Error | 134.87 | 37.52 | 120.34 | 43.04 |
| Min. Lat. Error | -124.94 | -58.31 | -143.49 | -74.28 |
| Avg. Abs. Lat. Error | 4.31 | 3.31 | 4.74 | 3.69 |
| Stddev. Abs. Lat. Error | 7.56 | 5.59 | 8.58 | 6.64 |
| Max. Abs. Lat. Error | 134.87 | 58.31 | 143.49 | 74.28 |
| Min. Abs. Lat. Error | 0 | 0 | 0 | 0 |
| Avg. Long. Error | 0.78 | 0.23 | 0.91 | 0.15 |
| Stddev. Long. Error | 8.71 | 8.65 | 9.93 | 9.95 |
| Max. Long. Error | 96.16 | 52.72 | 97.63 | 57.59 |
| Min. Long. Error | -109.33 | -58.39 | -99.82 | -56.73 |
| Avg. Abs. Long. Error | 5.71 | 5.82 | 6.61 | 6.79 |
| Stddev. Abs. Long. Error | 6.63 | 6.41 | 7.46 | 7.27 |
| Max. Abs. Long. Error | 109.33 | 58.39 | 99.82 | 57.59 |
| Min. Abs. Long. Error | 0 | 0.01 | 0 | 0 |
| Avg. Vert. Error | -211.73 | -137.64 | -273.57 | -273.83 |
| Stddev. Vert. Error | 2118.95 | 2082.79 | 2206.29 | 2285.65 |
| Max. Vert. Error | 37473.73 | 22311.16 | 38907.87 | 13328.09 |
| Min. Vert. Error | -15900 | -11900 | -15900 | -17219.3 |
| Avg. Abs. Vert. Error | 974.42 | 1079.43 | 1034.06 | 1237.03 |
| Stddev. Abs. Vert. Error | 1893.47 | 1786.4 | 1968.04 | 1941.13 |
| Max. Abs. Vert. Error | 37473.73 | 22311.16 | 38907.87 | 17219.3 |
| Min. Abs. Vert. Error | 0 | 0 | 0 | 0 |
| Avg. Slant Range Error | 8.37 | 7.63 | 9.48 | 8.79 |
| Stddev. Slant Range Error | 9.07 | 7.68 | 10.29 | 8.92 |
| Max. Slant Range Error | 173.7 | 59.78 | 156.48 | 75.02 |
| Min. Slant Range Error | 0.02 | 0.05 | 0.01 | 0.12 |

**Figure A.1- 91 Descriptive Statistics for Horizontal Phase of Flight per Look Ahead Time for Samples at All Altitudes**

| Look Ahead Time | 1800 | |
|---|---|---|
| Horizontal Phase of Flight | Straight | Turn |
| Sample Quantity | 5374 | 1070 |
| Avg. Horz. Error | 10.36 | 9.2 |
| Stddev. Horz. Error | 11.13 | 9.6 |
| Max. Horz. Error | 169.84 | 112.98 |
| Min. Horz. Error | 0.04 | 0.22 |
| Avg. Lat. Error | -0.25 | -0.08 |
| Stddev. Lat. Error | 10.33 | 8.55 |
| Max. Lat. Error | 117.09 | 53.32 |
| Min. Lat. Error | -155.99 | -91.1 |
| Avg. Abs. Lat. Error | 4.97 | 3.63 |
| Stddev. Abs. Lat. Error | 9.06 | 7.74 |
| Max. Abs. Lat. Error | 155.99 | 91.1 |
| Min. Abs. Lat. Error | 0 | 0 |
| Avg. Long. Error | 1.03 | 0.12 |
| Stddev. Long. Error | 11.11 | 10.19 |
| Max. Long. Error | 98.01 | 41.35 |
| Min. Long. Error | -78.53 | -66.82 |
| Avg. Abs. Long. Error | 7.46 | 7.23 |
| Stddev. Abs. Long. Error | 8.29 | 7.18 |
| Max. Abs. Long. Error | 98.01 | 66.82 |
| Min. Abs. Long. Error | 0 | 0.01 |
| Avg. Vert. Error | -353.57 | -194.44 |
| Stddev. Vert. Error | 2288.19 | 2344.76 |
| Max. Vert. Error | 31668.16 | 23241.93 |
| Min. Vert. Error | -15800 | -10068.2 |
| Avg. Abs. Vert. Error | 1079.65 | 1199.17 |
| Stddev. Abs. Vert. Error | 2048.16 | 2023.96 |
| Max. Abs. Vert. Error | 31668.16 | 23241.93 |
| Min. Abs. Vert. Error | 0 | 0 |
| Avg. Slant Range Error | 10.37 | 9.21 |
| Stddev. Slant Range Error | 11.12 | 9.6 |
| Max. Slant Range Error | 169.84 | 112.98 |
| Min. Slant Range Error | 0.04 | 0.23 |

**Figure A.1- 92 Descriptive Statistics for Horizontal Phase of Flight per Look Ahead Time for Samples at All Altitudes**

| Look Ahead Time | 0 | | 300 | |
|---|---|---|---|---|
| Horizontal Phase of Flight | Straight | Turn | Straight | Turn |
| Sample Quantity | 23358 | 2790 | 20257 | 2243 |
| Avg. Horz. Error | 1.14 | 1.12 | 3.17 | 3.25 |
| Stddev. Horz. Error | 0.96 | 0.81 | 3.51 | 3.8 |
| Max. Horz. Error | 42.39 | 8.85 | 84.31 | 65.56 |
| Min. Horz. Error | 0 | 0 | 0.01 | 0.03 |
| Avg. Lat. Error | -0.03 | -0.02 | -0.12 | -0.11 |
| Stddev. Lat. Error | 1.21 | 1.15 | 3.79 | 3.91 |
| Max. Lat. Error | 32.23 | 7.19 | 65.49 | 24.97 |
| Min. Lat. Error | -6.04 | -4.23 | -39.47 | -36.73 |
| Avg. Abs. Lat. Error | 0.8 | 0.8 | 2.02 | 2.07 |
| Stddev. Abs. Lat. Error | 0.9 | 0.82 | 3.21 | 3.32 |
| Max. Abs. Lat. Error | 32.23 | 7.19 | 65.49 | 36.73 |
| Min. Abs. Lat. Error | 0 | 0 | 0 | 0 |
| Avg. Long. Error | -0.02 | -0.05 | 0.14 | -0.03 |
| Stddev. Long. Error | 0.87 | 0.78 | 2.83 | 3.12 |
| Max. Long. Error | 11.93 | 8.82 | 25.52 | 22.3 |
| Min. Long. Error | -27.53 | -4.14 | -63.13 | -65.39 |
| Avg. Abs. Long. Error | 0.59 | 0.6 | 1.84 | 1.9 |
| Stddev. Abs. Long. Error | 0.64 | 0.5 | 2.16 | 2.48 |
| Max. Abs. Long. Error | 27.53 | 8.82 | 63.13 | 65.39 |
| Min. Abs. Long. Error | 0 | 0 | 0 | 0 |
| Avg. Vert. Error | 38.33 | 42.51 | 51.55 | 132.07 |
| Stddev. Vert. Error | 591.23 | 597.13 | 1466.04 | 1342.85 |
| Max. Vert. Error | 36817 | 21071.71 | 34817 | 9649 |
| Min. Vert. Error | -1838.97 | -2800 | -10304.6 | -6590 |
| Avg. Abs. Vert. Error | 135.31 | 150.04 | 598.37 | 582.81 |
| Stddev. Abs. Vert. Error | 576.81 | 579.53 | 1339.36 | 1216.91 |
| Max. Abs. Vert. Error | 36817 | 21071.71 | 34817 | 9649 |
| Min. Abs. Vert. Error | 0 | 0 | 0 | 0 |
| Avg. Slant Range Error | 1.14 | 1.12 | 3.19 | 3.26 |
| Stddev. Slant Range Error | 0.96 | 0.82 | 3.51 | 3.8 |
| Max. Slant Range Error | 42.39 | 8.85 | 84.34 | 65.56 |
| Min. Slant Range Error | 0 | 0 | 0.01 | 0.04 |

**Figure A.1- 93 Descriptive Statistics for Horizontal Phase of Flight per Look Ahead Time for Samples at Altitudes Above 18,000 Feet**

| Look Ahead Time | 600 | | 900 | |
|---|---|---|---|---|
| Horizontal Phase of Flight | Straight | Turn | Straight | Turn |
| Sample Quantity | 16318 | 1892 | 12490 | 1482 |
| Avg. Horz. Error | 5.24 | 5.06 | 7.02 | 6.72 |
| Stddev. Horz. Error | 5.7 | 5.75 | 7.64 | 7.69 |
| Max. Horz. Error | 125.68 | 92.46 | 167.79 | 150.3 |
| Min. Horz. Error | 0.02 | 0.03 | 0.03 | 0.06 |
| Avg. Lat. Error | -0.26 | 0 | -0.26 | -0.46 |
| Stddev. Lat. Error | 5.82 | 5.78 | 7.61 | 7.37 |
| Max. Lat. Error | 97.45 | 71.88 | 129.48 | 115.83 |
| Min. Lat. Error | -61.74 | -53.06 | -94.55 | -59.15 |
| Avg. Abs. Lat. Error | 3.08 | 2.89 | 3.95 | 3.58 |
| Stddev. Abs. Lat. Error | 4.95 | 5 | 6.5 | 6.46 |
| Max. Abs. Lat. Error | 97.45 | 71.88 | 129.48 | 115.83 |
| Min. Abs. Lat. Error | 0 | 0 | 0 | 0 |
| Avg. Long. Error | 0.46 | -0.09 | 0.57 | 0.34 |
| Stddev. Long. Error | 5.07 | 5.03 | 7.03 | 7.04 |
| Max. Long. Error | 91.73 | 25.18 | 94.25 | 27.07 |
| Min. Long. Error | -79.36 | -58.15 | -106.71 | -95.77 |
| Avg. Abs. Long. Error | 3.24 | 3.32 | 4.49 | 4.53 |
| Stddev. Abs. Long. Error | 3.93 | 3.77 | 5.45 | 5.4 |
| Max. Abs. Long. Error | 91.73 | 58.15 | 106.71 | 95.77 |
| Min. Abs. Long. Error | 0 | 0 | 0 | 0 |
| Avg. Vert. Error | 10.08 | 39.12 | -49.65 | 15.95 |
| Stddev. Vert. Error | 1820.98 | 1808.85 | 1853.61 | 1840.69 |
| Max. Vert. Error | 28933 | 14957.77 | 30746.5 | 25785.61 |
| Min. Vert. Error | -10552 | -9300 | -10700 | -8585.77 |
| Avg. Abs. Vert. Error | 771.03 | 779.41 | 779.51 | 775.96 |
| Stddev. Abs. Vert. Error | 1649.71 | 1632.69 | 1682.45 | 1669.09 |
| Max. Abs. Vert. Error | 28933 | 14957.77 | 30746.5 | 25785.61 |
| Min. Abs. Vert. Error | 0 | 0 | 0 | 0 |
| Avg. Slant Range Error | 5.25 | 5.07 | 7.03 | 6.73 |
| Stddev. Slant Range Error | 5.69 | 5.75 | 7.64 | 7.69 |
| Max. Slant Range Error | 125.72 | 92.49 | 167.86 | 150.36 |
| Min. Slant Range Error | 0.02 | 0.03 | 0.03 | 0.06 |

**Figure A.1- 94 Descriptive Statistics for Horizontal Phase of Flight per Look Ahead Time for Samples at Altitudes Above 18,000 Feet**

| Look Ahead Time | 1200 | | 1500 | |
|---|---|---|---|---|
| Horizontal Phase of Flight | Straight | Turn | Straight | Turn |
| Sample Quantity | 9175 | 1199 | 6431 | 876 |
| Avg. Horz. Error | 8.54 | 7.77 | 9.75 | 8.85 |
| Stddev. Horz. Error | 9.51 | 7.65 | 10.83 | 8.97 |
| Max. Horz. Error | 173.62 | 59.59 | 156.35 | 75.02 |
| Min. Horz. Error | 0.02 | 0.05 | 0.01 | 0.12 |
| Avg. Lat. Error | -0.21 | -0.66 | -0.33 | -0.74 |
| Stddev. Lat. Error | 9.39 | 7.4 | 10.51 | 8.11 |
| Max. Lat. Error | 134.87 | 31.72 | 120.34 | 43.04 |
| Min. Lat. Error | -124.94 | -58.31 | -143.49 | -74.28 |
| Avg. Abs. Lat. Error | 4.71 | 3.67 | 5.13 | 3.89 |
| Stddev. Abs. Lat. Error | 8.12 | 6.46 | 9.17 | 7.15 |
| Max. Abs. Lat. Error | 134.87 | 58.31 | 143.49 | 74.28 |
| Min. Abs. Lat. Error | 0 | 0 | 0 | 0 |
| Avg. Long. Error | 0.84 | 0.51 | 0.92 | 0.44 |
| Stddev. Long. Error | 8.63 | 7.96 | 10.06 | 9.61 |
| Max. Long. Error | 96.16 | 33.16 | 97.63 | 57.59 |
| Min. Long. Error | -109.33 | -39.15 | -99.82 | -56.73 |
| Avg. Abs. Long. Error | 5.57 | 5.59 | 6.61 | 6.66 |
| Stddev. Abs. Long. Error | 6.65 | 5.69 | 7.63 | 6.94 |
| Max. Abs. Long. Error | 109.33 | 39.15 | 99.82 | 57.59 |
| Min. Abs. Long. Error | 0 | 0.01 | 0 | 0 |
| Avg. Vert. Error | -111.93 | -35.3 | -173.17 | -139.25 |
| Stddev. Vert. Error | 1930.07 | 1895.78 | 2047.12 | 1894.59 |
| Max. Vert. Error | 37473.73 | 22311.16 | 38907.87 | 13328.09 |
| Min. Vert. Error | -10485.7 | -7974.83 | -9483.61 | -8910.64 |
| Avg. Abs. Vert. Error | 771.12 | 819.37 | 836.94 | 858.13 |
| Stddev. Abs. Vert. Error | 1772.85 | 1709.76 | 1876.19 | 1694.6 |
| Max. Abs. Vert. Error | 37473.73 | 22311.16 | 38907.87 | 13328.09 |
| Min. Abs. Vert. Error | 0 | 0 | 0 | 0 |
| Avg. Slant Range Error | 8.55 | 7.78 | 9.76 | 8.86 |
| Stddev. Slant Range Error | 9.51 | 7.64 | 10.83 | 8.96 |
| Max. Slant Range Error | 173.7 | 59.59 | 156.48 | 75.02 |
| Min. Slant Range Error | 0.02 | 0.05 | 0.01 | 0.12 |

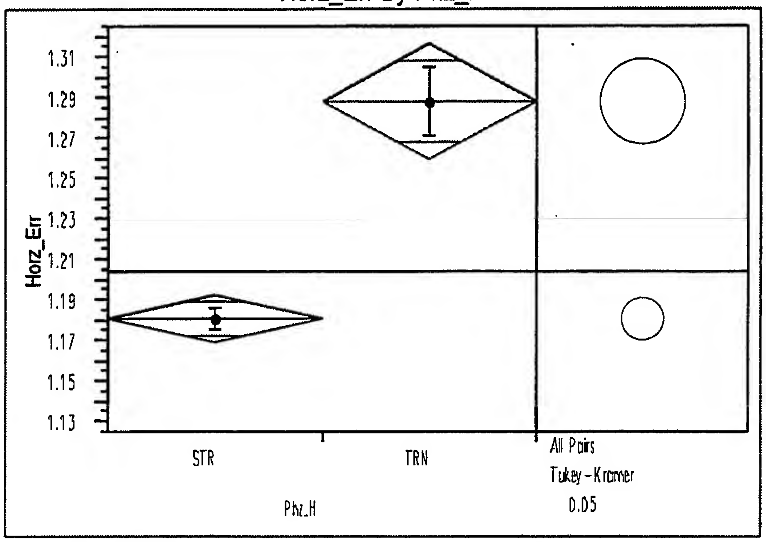
**Figure A.1- 95 Descriptive Statistics for Horizontal Phase of Flight per Look Ahead Time for Samples at Altitudes Above 18,000 Feet**

| Look Ahead Time | 1800 | |
|---|---|---|
| Horizontal Phase of Flight | Straight | Turn |
| Sample Quantity | 4254 | 637 |
| Avg. Horz. Error | 10.78 | 9.51 |
| Stddev. Horz. Error | 11.7 | 10.41 |
| Max. Horz. Error | 169.84 | 112.98 |
| Min. Horz. Error | 0.04 | 0.24 |
| Avg. Lat. Error | -0.4 | -0.74 |
| Stddev. Lat. Error | 10.93 | 9.48 |
| Max. Lat. Error | 117.09 | 29.62 |
| Min. Lat. Error | -155.99 | -91.1 |
| Avg. Abs. Lat. Error | 5.27 | 3.83 |
| Stddev. Abs. Lat. Error | 9.58 | 8.7 |
| Max. Abs. Lat. Error | 155.99 | 91.1 |
| Min. Abs. Lat. Error | 0 | 0 |
| Avg. Long. Error | 0.95 | -0.39 |
| Stddev. Long. Error | 11.52 | 10.41 |
| Max. Long. Error | 98.01 | 41.35 |
| Min. Long. Error | -78.53 | -66.82 |
| Avg. Abs. Long. Error | 7.66 | 7.31 |
| Stddev. Abs. Long. Error | 8.66 | 7.41 |
| Max. Abs. Long. Error | 98.01 | 66.82 |
| Min. Abs. Long. Error | 0 | 0.01 |
| Avg. Vert. Error | -210.65 | 23.33 |
| Stddev. Vert. Error | 2127.36 | 2234.08 |
| Max. Vert. Error | 31668.16 | 23241.93 |
| Min. Vert. Error | -10550 | -8192.79 |
| Avg. Abs. Vert. Error | 885.61 | 945.76 |
| Stddev. Abs. Vert. Error | 1945.65 | 2023.8 |
| Max. Abs. Vert. Error | 31668.16 | 23241.93 |
| Min. Abs. Vert. Error | 0 | 0 |
| Avg. Slant Range Error | 10.8 | 9.52 |
| Stddev. Slant Range Error | 11.7 | 10.4 |
| Max. Slant Range Error | 169.84 | 112.98 |
| Min. Slant Range Error | 0.04 | 0.36 |

**Figure A.1- 96 Descriptive Statistics for Horizontal Phase of Flight per Look Ahead Time for Samples at Altitudes Above 18,000 Feet**

## A.1.3.2 Statistical Tests

Horz_Err By Phz_H




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 30644 | 1.18965 | 1.04870 | 0.00599 |
| TRN | 5284 | 1.29264 | 1.26544 | 0.01741 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | TRN | STR |
|---|---|---|
| TRN | 0.000000 | 0.102987 |
| STR | -0.10299 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96003

| Abs(Dif)-LSD | TRN | STR |
|---|---|---|
| TRN | -0.04131 | 0.071358 |
| STR | 0.071358 | -0.01715 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 30644 | 1.048704 | 0.7002294 | 0.6736421 |
| TRN | 5284 | 1.265439 | 0.7923162 | 0.7528604 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 9.1359 | 1 | 35926 | 0.0025 |
| Brown-Forsythe | 37.0686 | 1 | 35926 | <.0001 |
| Levene | 57.6468 | 1 | 35926 | <.0001 |
| Bartlett | 346.9744 | 1 | ? | <.0001 |

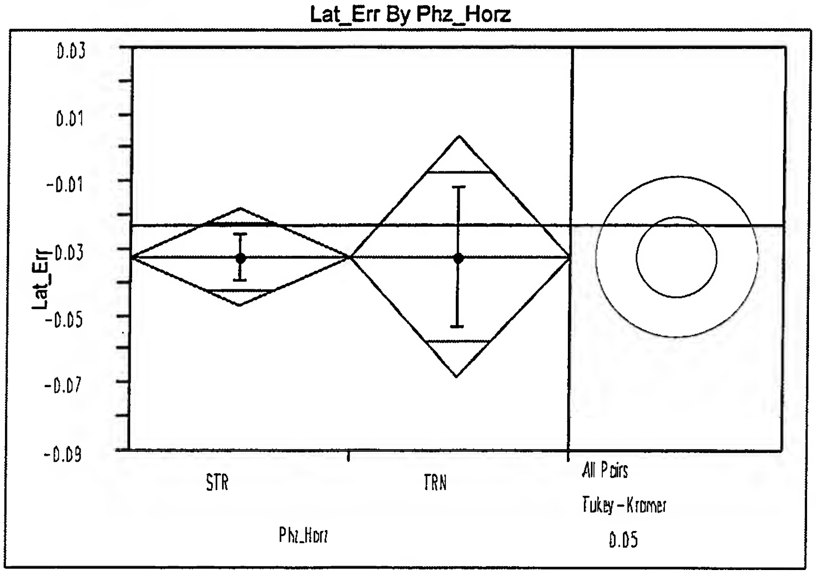
Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 31.2921 | 1 | 6592.4 | <.0001 |

t-Test

5.5939

**Figure A.1- 97 Statistical Tests for Horizontal Error and Horizontal Phase of Flight at Look Ahead Time 0 for Samples at All Altitudes**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 30644 | -0.02227 | 1.30628 | 0.00746 |
| TRN | 5284 | -0.0265 | 1.53523 | 0.02112 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | STR | TRN |
|---|---|---|
| STR | 0.000000 | 0.004228 |
| TRN | -0.00423 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96003

| Abs(Dif)-LSD | STR | TRN |
|---|---|---|
| STR | -0.02126 | -0.03496 |
| TRN | -0.03496 | -0.05119 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 30644 | 1.306283 | 0.8559916 | 0.8557251 |
| TRN | 5284 | 1.535231 | 0.9606380 | 0.9599589 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 28.5693 | 1 | 35926 | <.0001 |
| Brown-Forsythe | 46.9795 | 1 | 35926 | <.0001 |
| Levene | 47.3959 | 1 | 35926 | <.0001 |
| Bartlett | 253.3457 | 1 | ? | <.0001 |

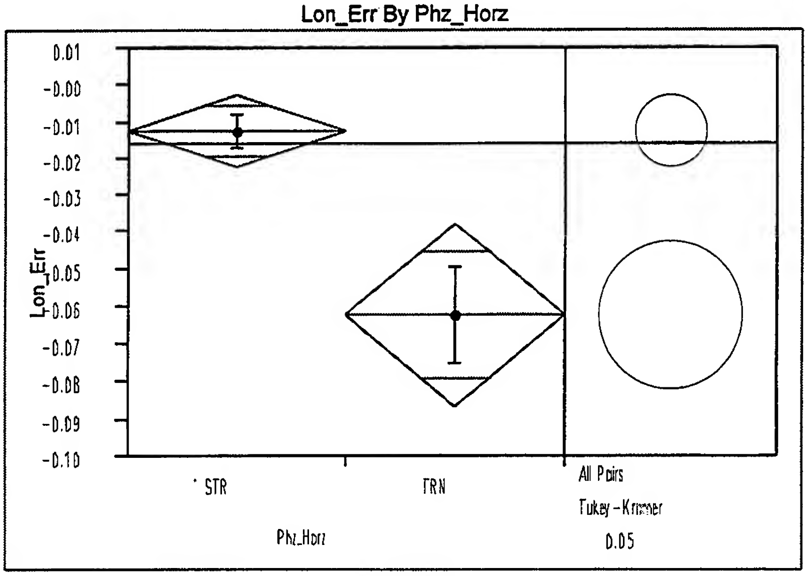
Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 0.0356 | 1 | 6666.5 | 0.8503 |

t-Test
0.1888

**Figure A.1- 98 Statistical Tests for Lateral Error and Horizontal Phase of Flight at Look Ahead Time 0 for Samples at All Altitudes**

Lon_Err By Phz_Horz




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 30644 | -0.00921 | 0.898964 | 0.00514 |
| TRN | 5284 | -0.05507 | 0.954927 | 0.01314 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | STR | TRN |
|---|---|---|
| STR | 0.000000 | 0.045861 |
| TRN | -0.04586 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96003

| Abs(Dif)-LSD | STR | TRN |
|---|---|---|
| STR | -0.01437 | 0.019368 |
| TRN | 0.019368 | -0.0346 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 30644 | 0.8989641 | 0.6020186 | 0.6020029 |
| TRN | 5284 | 0.9549275 | 0.6440687 | 0.6434889 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 1.2949 | 1 | 35926 | 0.2552 |
| Brown-Forsythe | 17.1044 | 1 | 35926 | <.0001 |
| Levene | 17.5826 | 1 | 35926 | <.0001 |
| Bartlett | 33.8112 | 1 | ? | <.0001 |

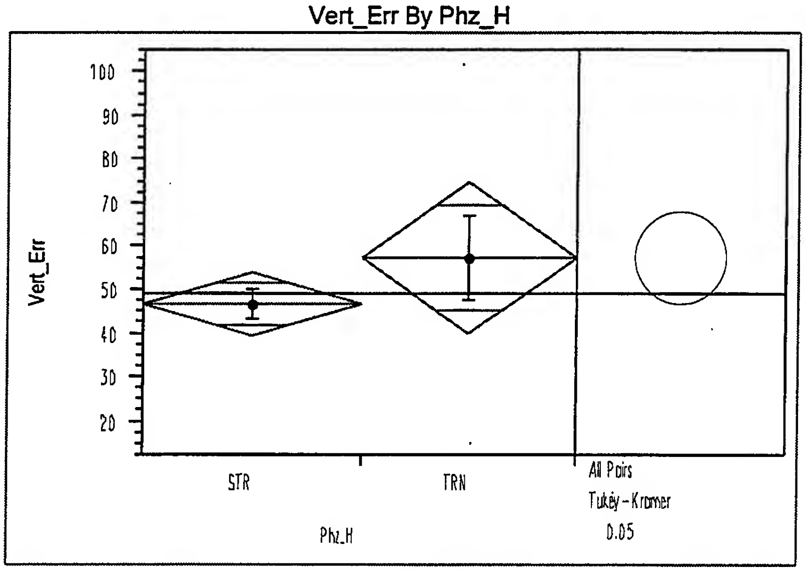
Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 10.5717 | 1 | 6992.8 | 0.0012 |

t-Test

3.2514

**Figure A.1- 99 Statistical Tests for Longitudinal Error and Horizontal Phase of Flight at Look Ahead Time 0 for Samples at All Altitudes**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 30644 | 47.1888 | 649.950 | 3.713 |
| TRN | 5284 | 61.9253 | 733.672 | 10.093 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | TRN | STR |
|---|---|---|
| TRN | 0.0000 | 14.7365 |
| STR | -14.7365 | 0.0000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96003

| Abs(Dif)-LSD | TRN | STR |
|---|---|---|
| TRN | -25.2791 | -4.6183 |
| STR | -4.6183 | -10.4971 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 30644 | 649.9503 | 217.6595 | 193.1017 |
| TRN | 5284 | 733.6721 | 292.4736 | 268.0528 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 0.5220 | 1 | 35926 | 0.4700 |
| Brown-Forsythe | 63.3651 | 1 | 35926 | <.0001 |
| Levene | 65.2706 | 1 | 35926 | <.0001 |
| Bartlett | 139.9948 | 1 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

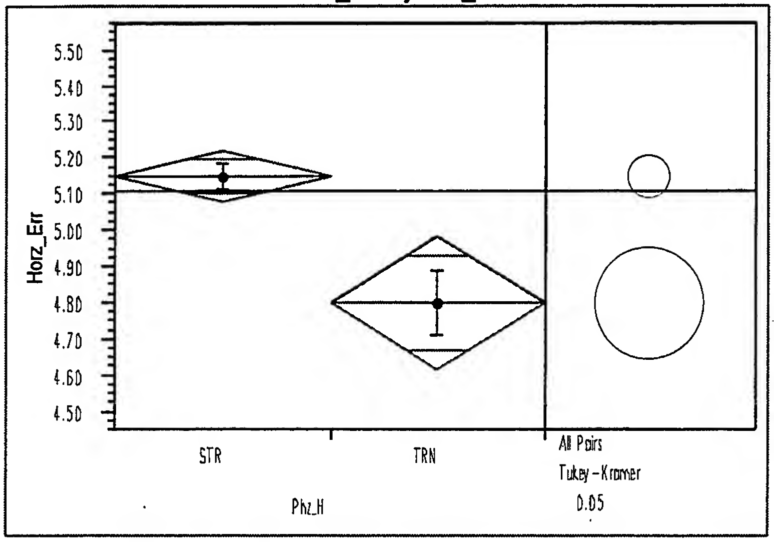
| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 1.8777 | 1 | 6788.1 | 0.1706 |

t-Test

1.3703

**Figure A.1- 100 Statistical Tests for Vertical Error and Horizontal Phase of Flight at Look Ahead Time 0 for Samples at All Altitudes**

Horz_Err By Phz_H




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 20696 | 5.15568 | 5.49140 | 0.03817 |
| TRN | 3268 | 4.80602 | 5.29839 | 0.09268 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | STR | TRN |
|---|---|---|
| STR | 0.000000 | 0.349667 |
| TRN | -0.34967 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96007

| Abs(Dif)-LSD | STR | TRN |
|---|---|---|
| STR | -0.10531 | 0.148018 |
| TRN | 0.148018 | -0.26502 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 20696 | 5.491399 | 3.696338 | 3.394160 |
| TRN | 3268 | 5.298388 | 3.416439 | 3.143605 |

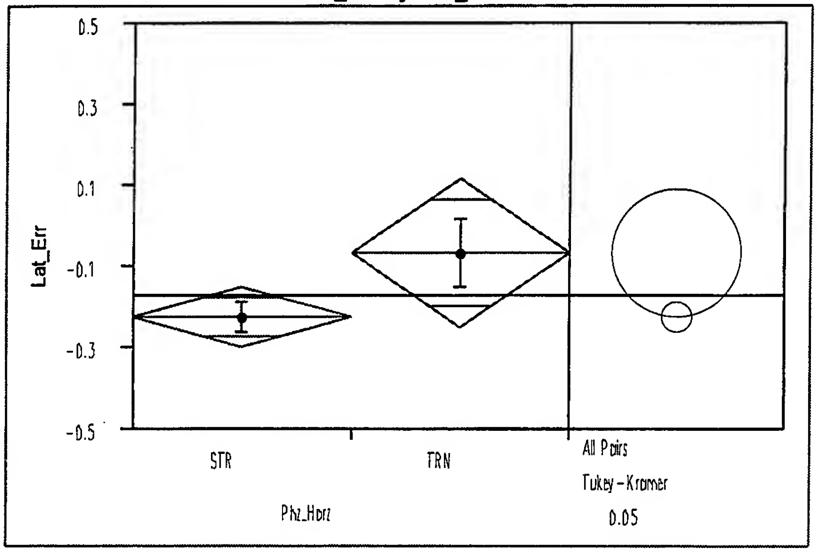
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 0.3511 | 1 | 23962 | 0.5535 |
| Brown-Forsythe | 8.2575 | 1 | 23962 | 0.0041 |
| Levene | 13.4178 | 1 | 23962 | 0.0002 |
| Bartlett | 7.0994 | 1 | ? | 0.0077 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 12.1691 | 1 | 4449.1 | 0.0005 |
| t-Test | | | |
| 3.4884 | | | |

**Figure A.1- 101 Statistical Tests for Horizontal Error and Horizontal Phase of Flight at Look Ahead Time 600 for Samples at All Altitudes**

Lat_Err By Phz_Horz




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 20696 | -0.18927 | 5.49054 | 0.03817 |
| TRN | 3268 | -0.05444 | 5.05091 | 0.08835 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | TRN | STR |
|---|---|---|
| TRN | 0.000000 | 0.134832 |
| STR | -0.13483 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96007

| Abs(Dif)-LSD | TRN | STR |
|---|---|---|
| TRN | -0.26343 | -0.06561 |
| STR | -0.06561 | -0.10468 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 20696 | 5.490536 | 2.923887 | 2.903638 |
| TRN | 3268 | 5.050909 | 2.617246 | 2.614011 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 3.2794 | 1 | 23962 | 0.0702 |
| Brown-Forsythe | 11.0991 | 1 | 23962 | 0.0009 |
| Levene | 12.5203 | 1 | 23962 | 0.0004 |
| Bartlett | 37.7387 | 1 | ? | <.0001 |

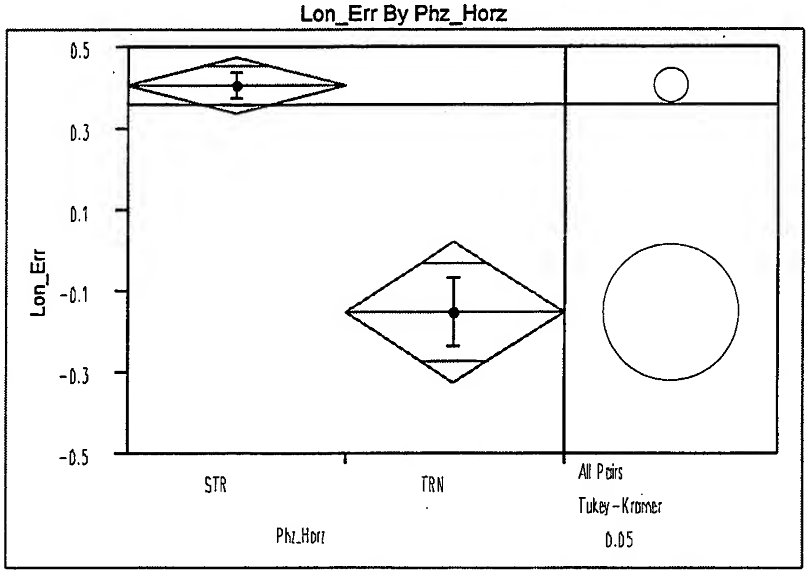
Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 1.9626 | 1 | 4574.8 | 0.1613 |

t-Test

1.4009

**Figure A.1- 102 Statistical Tests for Lateral Error and Horizontal Phase of Flight at Look Ahead Time 600 for Samples at All Altitudes**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 20696 | 0.440978 | 5.13435 | 0.03569 |
| TRN | 3268 | -0.14195 | 5.06389 | 0.08858 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | STR | TRN |
|---|---|---|
| STR | 0.000000 | 0.582923 |
| TRN | -0.58292 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96007

| Abs(Dif)-LSD | STR | TRN |
|---|---|---|
| STR | -0.09875 | 0.393844 |
| TRN | 0.393844 | -0.2485 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 20696 | 5.134348 | 3.305220 | 3.302728 |
| TRN | 3268 | 5.063891 | 3.272833 | 3.268000 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 0.0758 | 1 | 23962 | 0.7830 |
| Brown-Forsythe | 0.2209 | 1 | 23962 | 0.6383 |
| Levene | 0.1926 | 1 | 23962 | 0.6607 |
| Bartlett | 1.0701 | 1 | ? | 0.3009 |

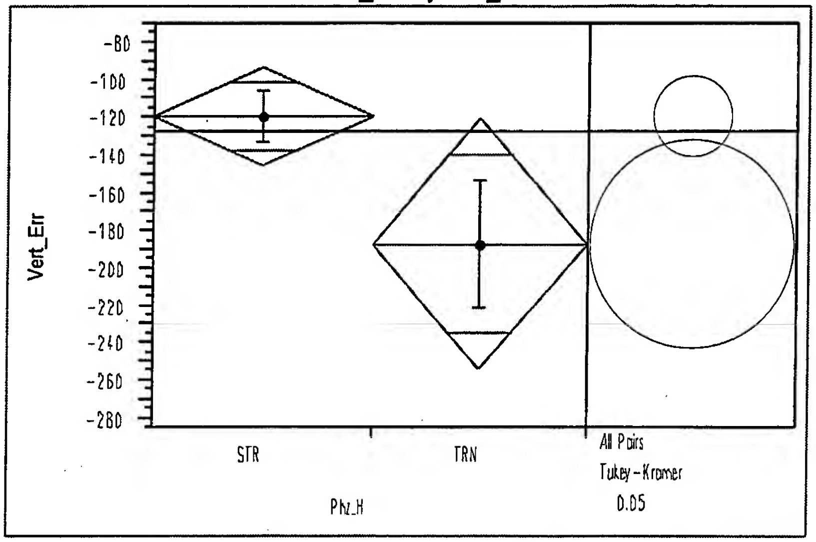
Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 37.2569 | 1 | 4395.5 | <.0001 |

| t-Test |
|---|
| 6.1038 |

**Figure A.1- 103 Statistical Tests for Longitudinal Error and Horizontal Phase of Flight at Look Ahead Time 600 for Samples at All Altitudes**

Vert_Err By Phz_H




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 20696 | -117.996 | 1956.29 | 13.598 |
| TRN | 3268 | -180.929 | 1989.43 | 34.801 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | STR | TRN |
|---|---|---|
| STR | 0.0000 | 62.9333 |
| TRN | -62.9333 | 0.0000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q*

1.96007

| Abs(Dif)-LSD | STR | TRN |
|---|---|---|
| STR | -37.7820 | -9.4117 |
| TRN | -9.4117 | -95.0795 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 20696 | 1956.291 | 967.748 | 908.3291 |
| TRN | 3268 | 1989.430 | 1059.898 | 978.4901 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 0.2293 | 1 | 23962 | 0.6321 |
| Brown-Forsythe | 4.6031 | 1 | 23962 | 0.0319 |
| Levene | 8.3135 | 1 | 23962 | 0.0039 |
| Bartlett | 1.6052 | 1 | ? | 0.2052 |

Welch Anova testing Means Equal, allowing Std's Not Equal

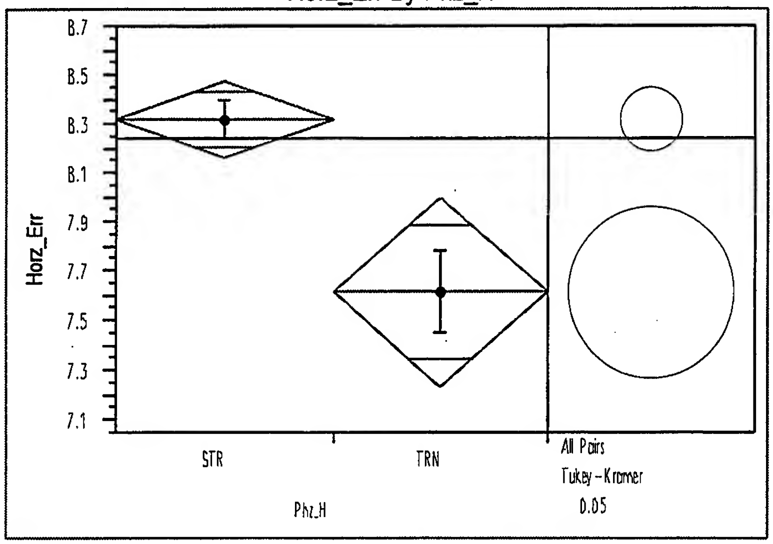
| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 2.8371 | 1 | 4324.9 | 0.0922 |

t-Test

1.6844

**Figure A.1- 104 Statistical Tests for Vertical Error and Horizontal Phase of Flight at Look Ahead Time 600 for Samples at All Altitudes**

Horz_Err By Phz_H




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 11777 | 8.35655 | 9.07761 | 0.08365 |
| TRN | 2059 | 7.62214 | 7.68013 | 0.16925 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | STR | TRN |
|---|---|---|
| STR | 0.000000 | 0.734415 |
| TRN | -0.73442 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96014

| Abs(Dif)-LSD | STR | TRN |
|---|---|---|
| STR | -0.22692 | 0.318468 |
| TRN | 0.318468 | -0.54271 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 11777 | 9.077615 | 5.894810 | 5.459758 |
| TRN | 2059 | 7.680126 | 5.365415 | 4.950048 |

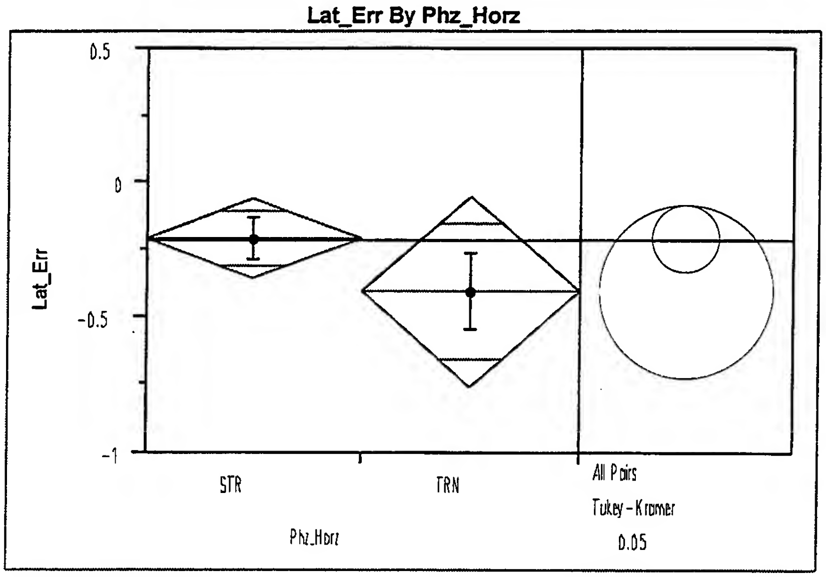
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 3.7312 | 1 | 13834 | 0.0534 |
| Brown-Forsythe | 8.0307 | 1 | 13834 | 0.0046 |
| Levene | 10.9023 | 1 | 13834 | 0.0010 |
| Bartlett | 90.4771 | 1 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 15.1320 | 1 | 3153.2 | 0.0001 |

t-Test
3.8900

**Figure A.1- 105 Statistical Tests for Horizontal Error and Horizontal Phase of Flight at Look Ahead Time 1200 for Samples at All Altitudes**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 11777 | -0.18974 | 8.69899 | 0.08016 |
| TRN | 2059 | -0.34514 | 6.48552 | 0.14293 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | STR | TRN |
|---|---|---|
| STR | 0.000000 | 0.155399 |
| TRN | -0.1554 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96014

| Abs(Dif)-LSD | STR | TRN |
|---|---|---|
| STR | -0.21474 | -0.23822 |
| TRN | -0.23822 | -0.51357 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 11777 | 8.698985 | 4.327187 | 4.305173 |
| TRN | 2059 | 6.485523 | 3.369102 | 3.310283 |

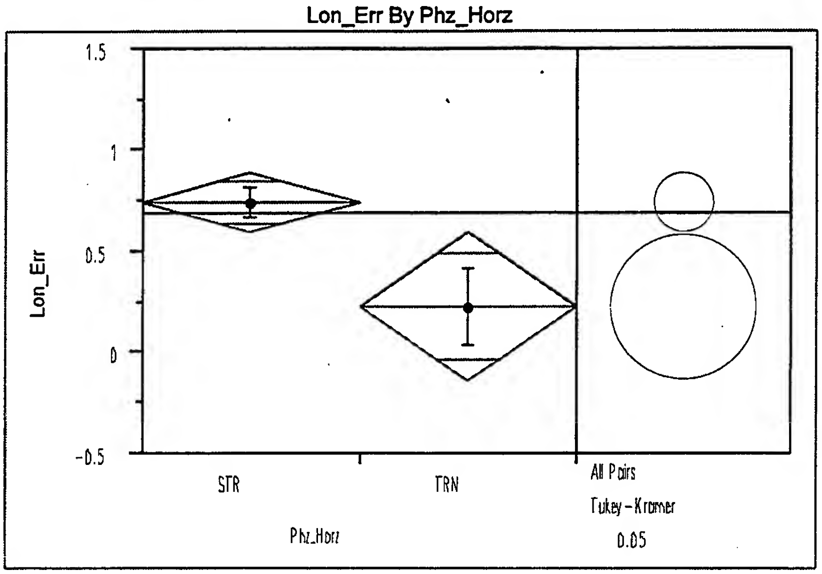
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 12.0914 | 1 | 13834 | 0.0005 |
| Brown-Forsythe | 32.5365 | 1 | 13834 | <.0001 |
| Levene | 30.3294 | 1 | 13834 | <.0001 |
| Bartlett | 262.8820 | 1 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 0.8993 | 1 | 3495.8 | 0.3430 |

t-Test
0.9483

**Figure A.1- 106 Statistical Tests for Lateral Error and Horizontal Phase of Flight at Look Ahead Time 1200 for Samples at All Altitudes**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 11777 | 0.775014 | 8.71389 | 0.08030 |
| TRN | 2059 | 0.234513 | 8.65294 | 0.19069 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | STR | TRN |
|---|---|---|
| STR | 0.000000 | 0.540501 |
| TRN | -0.5405 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96014

| Abs(Dif)-LSD | STR | TRN |
|---|---|---|
| STR | -0.22235 | 0.132926 |
| TRN | 0.132926 | -0.53178 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 11777 | 8.713893 | 5.676709 | 5.676294 |
| TRN | 2059 | 8.652936 | 5.808816 | 5.807731 |

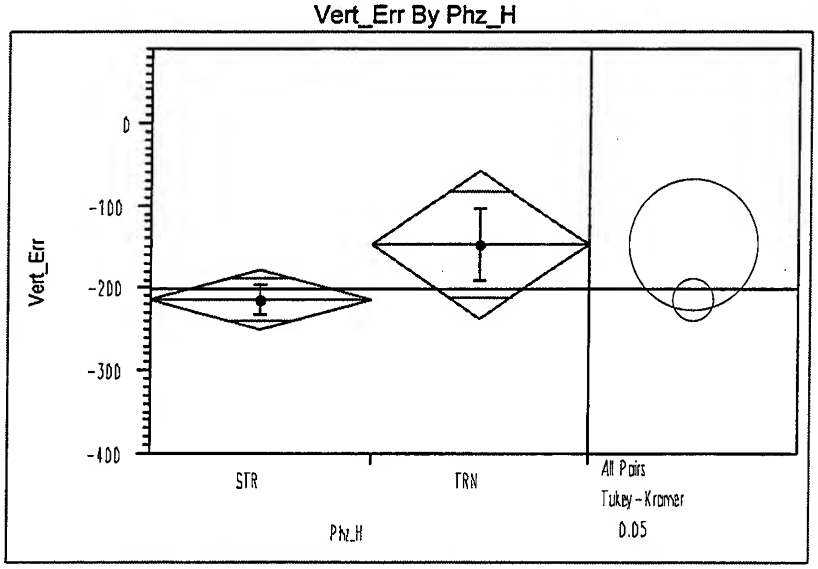
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 0.0194 | 1 | 13834 | 0.8891 |
| Brown-Forsythe | 0.6987 | 1 | 13834 | 0.4032 |
| Levene | 0.7061 | 1 | 13834 | 0.4008 |
| Bartlett | 0.1721 | 1 | ? | 0.6783 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 6.8239 | 1 | 2836.9 | 0.0090 |

t-Test
2.6123

**Figure A.1- 107 Statistical Tests for Longitudinal Error and Horizontal Phase of Flight at Look Ahead Time 1200 for Samples at All Altitudes**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 11777 | -211.733 | 2118.95 | 19.526 |
| TRN | 2059 | -137.636 | 2082.79 | 45.901 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | TRN | STR |
|---|---|---|
| TRN | 0.0000 | 74.0965 |
| STR | -74.0965 | 0.0000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96014

| Abs(Dif)-LSD | TRN | STR |
|---|---|---|
| TRN | -129.122 | -24.866 |
| STR | -24.866 | -53.990 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 11777 | 2118.952 | 1083.927 | 974.422 |
| TRN | 2059 | 2082.791 | 1137.760 | 1079.431 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 0.0647 | 1 | 13834 | 0.7993 |
| Brown-Forsythe | 5.4800 | 1 | 13834 | 0.0192 |
| Levene | 1.5511 | 1 | 13834 | 0.2130 |
| Bartlett | 1.0296 | 1 | ? | 0.3103 |

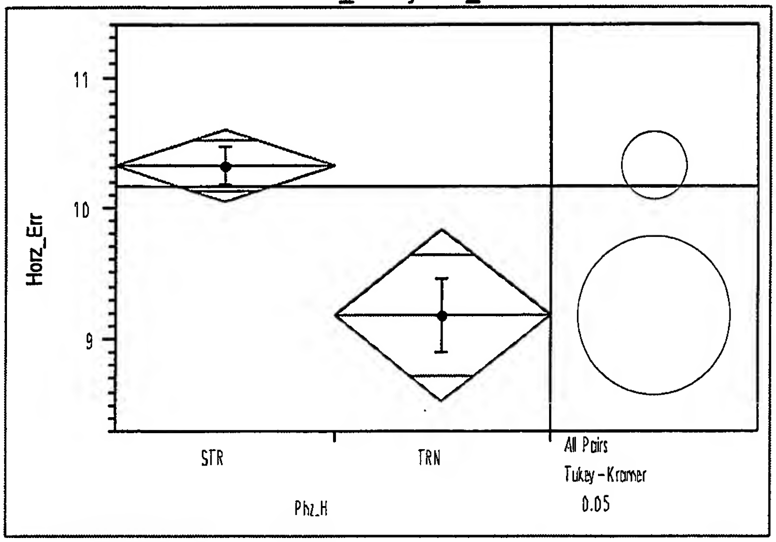
Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 2.2066 | 1 | 2853.9 | 0.1375 |

t-Test
1.4855

**Figure A.1- 108 Statistical Tests for Vertical Error and Horizontal Phase of Flight at Look Ahead Time 1200 for Samples at All Altitudes**

Horz_Err By Phz_H




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 5374 | 10.3600 | 11.1290 | 0.15181 |
| TRN | 1070 | 9.1972 | 9.6037 | 0.29359 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | STR | TRN |
|---|---|---|
| STR | 0.00000 | 1.16277 |
| TRN | -1.16277 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96033

| Abs(Dif)-LSD | STR | TRN |
|---|---|---|
| STR | -0.41186 | 0.448073 |
| TRN | 0.448073 | -0.92301 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 5374 | 11.12897 | 7.176342 | 6.645693 |
| TRN | 1070 | 9.60369 | 6.144044 | 5.673951 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 2.3236 | 1 | 6442 | 0.1275 |
| Brown-Forsythe | 9.8134 | 1 | 6442 | 0.0017 |
| Levene | 13.7068 | 1 | 6442 | 0.0002 |
| Bartlett | 36.2444 | 1 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

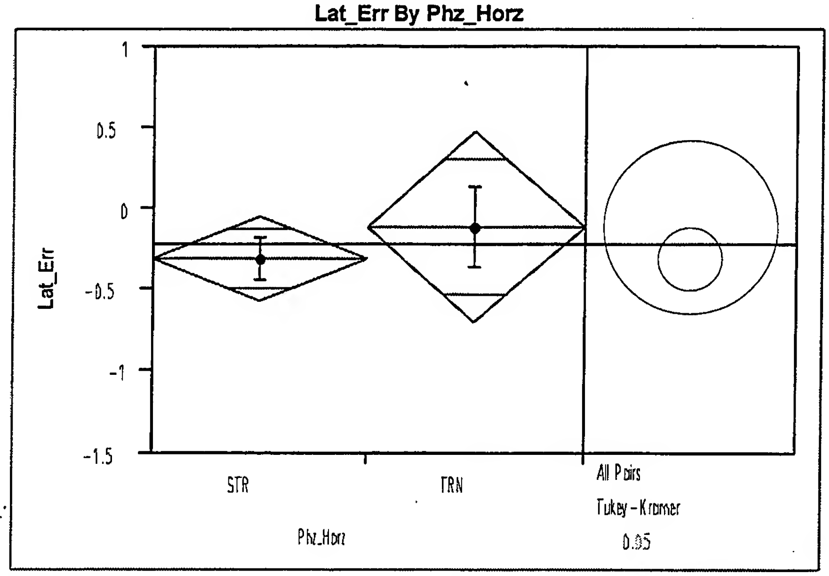
| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 12.3762 | 1 | 1693 | 0.0004 |

t-Test

3.5180

**Figure A.1- 109 Statistical Tests for Horizontal Error and Horizontal Phase of Flight at Look Ahead Time 1800 for Samples at All Altitudes**

Lat_Err By Phz_Horz




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 5374 | -0.24902 | 10.3318 | 0.14094 |
| TRN | 1070 | -0.08491 | 8.5473 | 0.26130 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | TRN | STR |
|---|---|---|
| TRN | 0.000000 | 0.164114 |
| STR | -0.16411 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96033

| Abs(Dif)-LSD | TRN | STR |
|---|---|---|
| TRN | -0.85241 | -0.49591 |
| STR | -0.49591 | -0.38036 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 5374 | 10.33181 | 5.002420 | 4.965469 |
| TRN | 1070 | 8.54733 | 3.637925 | 3.623850 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 2.8305 | 1 | 6442 | 0.0925 |
| Brown-Forsythe | 20.4680 | 1 | 6442 | <.0001 |
| Levene | 21.2774 | 1 | 6442 | <.0001 |
| Bartlett | 58.8292 | 1 | ? | <.0001 |

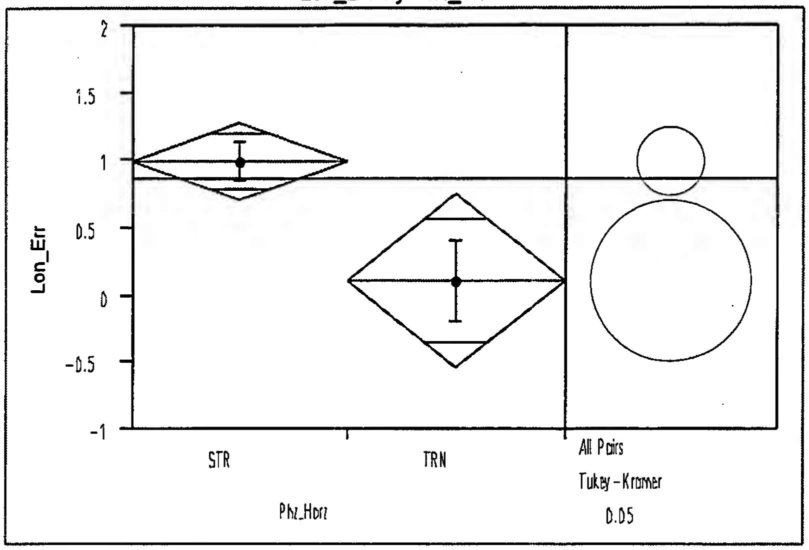
Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 0.3056 | 1 | 1752 | 0.5805 |

t-Test
0.5528

**Figure A.1- 110 Statistical Tests for Lateral Error and Horizontal Phase of Flight at Look Ahead Time 1800 for Samples at All Altitudes**

Lon_Err By Phz_Horz




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 5374 | 1.02607 | 11.1059 | 0.15150 |
| TRN | 1070 | 0.11968 | 10.1892 | 0.31149 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | STR | TRN |
|---|---|---|
| STR | 0.000000 | 0.906391 |
| TRN | -0.90639 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96033

| Abs(Dif)-LSD | STR | TRN |
|---|---|---|
| STR | -0.41445 | 0.187202 |
| TRN | 0.187202 | -0.92881 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 5374 | 11.10594 | 7.405065 | 7.404787 |
| TRN | 1070 | 10.18923 | 7.222062 | 7.219848 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 2.4553 | 1 | 6442 | 0.1172 |
| Brown-Forsythe | 0.4644 | 1 | 6442 | 0.4956 |
| Levene | 0.4549 | 1 | 6442 | 0.5000 |
| Bartlett | 12.7285 | 1 | ? | 0.0004 |

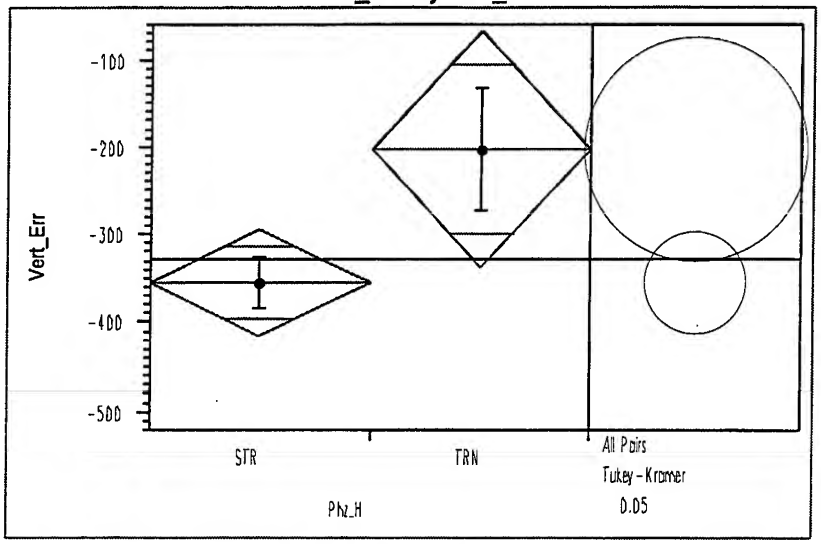
Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 6.8474 | 1 | 1616.6 | 0.0090 |

t-Test
2.6167

**Figure A.1- 111 Statistical Tests for Longitudinal Error and Horizontal Phase of Flight at Look Ahead Time 1800 for Samples at All Altitudes**

Vert_Err By Phz_H




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 5374 | -353.572 | 2288.19 | 31.213 |
| TRN | 1070 | -194.444 | 2344.76 | 71.681 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | TRN | STR |
|---|---|---|
| TRN | 0.000 | 159.127 |
| STR | -159.127 | 0.000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96033

| Abs(Dif)-LSD | TRN | STR |
|---|---|---|
| TRN | -194.734 | 8.344 |
| STR | 8.344 | -86.893 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 5374 | 2288.185 | 1260.318 | 1079.647 |
| TRN | 1070 | 2344.763 | 1278.268 | 1199.168 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 0.0756 | 1 | 6442 | 0.7834 |
| Brown-Forsythe | 3.0506 | 1 | 6442 | 0.0808 |
| Levene | 0.0781 | 1 | 6442 | 0.7799 |
| Bartlett | 1.0751 | 1 | ? | 0.2998 |

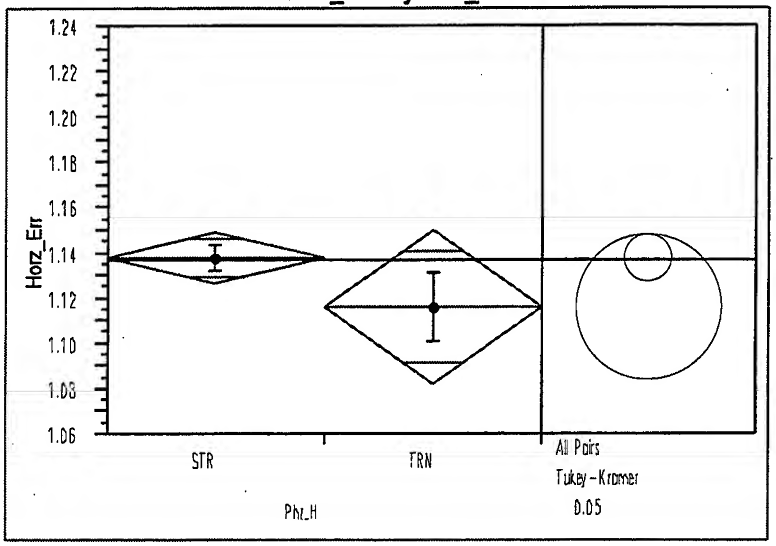
Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 4.1426 | 1 | 1502.1 | 0.0420 |

t-Test
2.0353

**Figure A.1- 112 Statistical Tests for Vertical Error and Horizontal Phase of Flight at Look Ahead Time 1800 for Samples at All Altitudes**

## Horz_Err By Phz_H




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 23358 | 1.13878 | 0.956849 | 0.00626 |
| TRN | 2790 | 1.12099 | 0.814684 | 0.01542 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | STR | TRN |
|---|---|---|
| STR | 0.000000 | 0.017799 |
| TRN | -0.0178 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96006

| Abs(Dif)-LSD | STR | TRN |
|---|---|---|
| STR | -0.0171 | -0.01921 |
| TRN | -0.01921 | -0.04947 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 23358 | 0.9568488 | 0.6543072 | 0.6331895 |
| TRN | 2790 | 0.8146839 | 0.6252144 | 0.6084381 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 1.1246 | 1 | 26146 | 0.2889 |
| Brown-Forsythe | 2.8779 | 1 | 26146 | 0.0898 |
| Levene | 4.5412 | 1 | 26146 | 0.0331 |
| Bartlett | 118.5084 | 1 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

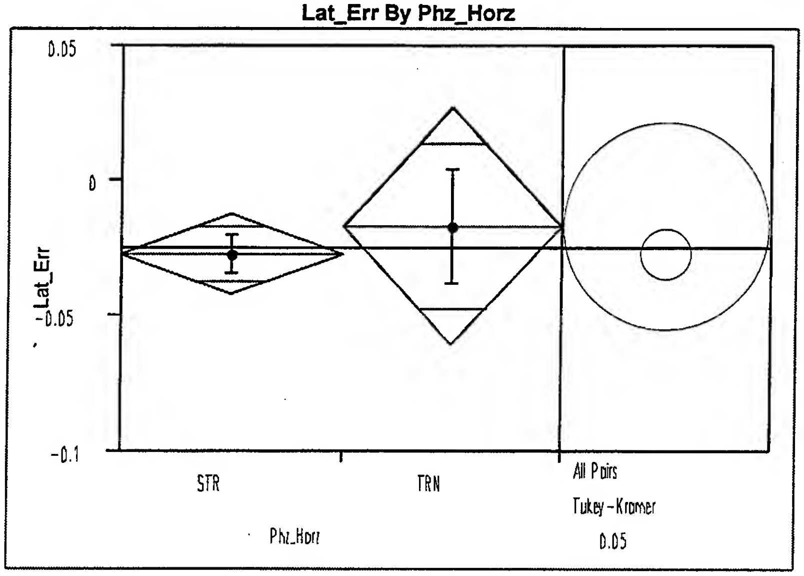
| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 1.1433 | 1 | 3771.6 | 0.2850 |

t-Test

1.0693

**Figure A.1- 113 Statistical Tests for Horizontal Error and Horizontal Phase of Flight at Look Ahead Time 0 for Samples at Altitudes Above 18,000 Feet**

Lat_Err By Phz_Horz




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 23358 | -0.02597 | 1.20545 | 0.00789 |
| TRN | 2790 | -0.01611 | 1.14651 | 0.02171 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | TRN | STR |
|---|---|---|
| TRN | 0.000000 | 0.009859 |
| STR | -0.00986 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96006

| Abs(Dif)-LSD | TRN | STR |
|---|---|---|
| TRN | -0.06294 | -0.03723 |
| STR | -0.03723 | -0.02175 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 23358 | 1.205451 | 0.8046062 | 0.8042065 |
| TRN | 2790 | 1.146515 | 0.7982615 | 0.7978787 |

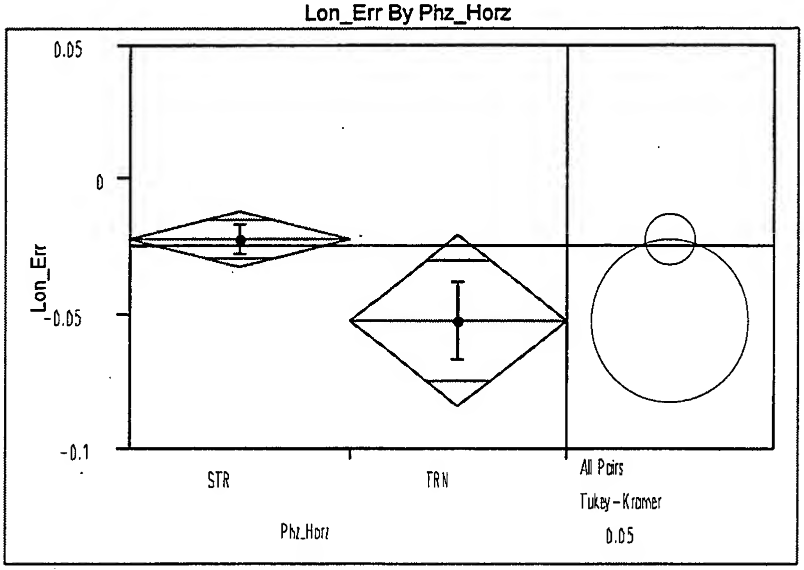
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 0.8749 | 1 | 26146 | 0.3496 |
| Brown-Forsythe | 0.1258 | 1 | 26146 | 0.7228 |
| Levene | 0.1267 | 1 | 26146 | 0.7219 |
| Bartlett | 12.1946 | 1 | ? | 0.0005 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 0.1822 | 1 | 3566.7 | 0.6695 |

t-Test
0.4269

**Figure A.1- 114 Statistical Tests for Lateral Error and Horizontal Phase of Flight at Look Ahead Time 0 for Samples at Altitudes Above 18,000 Feet**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 23358 | -0.02193 | 0.870736 | 0.00570 |
| TRN | 2790 | -0.04635 | 0.777087 | 0.01471 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | STR | TRN |
|---|---|---|
| STR | 0.000000 | 0.024420 |
| TRN | -0.02442 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96006

| Abs(Dif)-LSD | STR | TRN |
|---|---|---|
| STR | -0.01562 | -0.00939 |
| TRN | -0.00939 | -0.0452 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 23358 | 0.8707357 | 0.5903900 | 0.5903219 |
| TRN | 2790 | 0.7770872 | 0.5965265 | 0.5965178 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 1.3093 | 1 | 26146 | 0.2525 |
| Brown-Forsythe | 0.2437 | 1 | 26146 | 0.6215 |
| Levene | 0.2392 | 1 | 26146 | 0.6248 |
| Bartlett | 60.7791 | 1 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

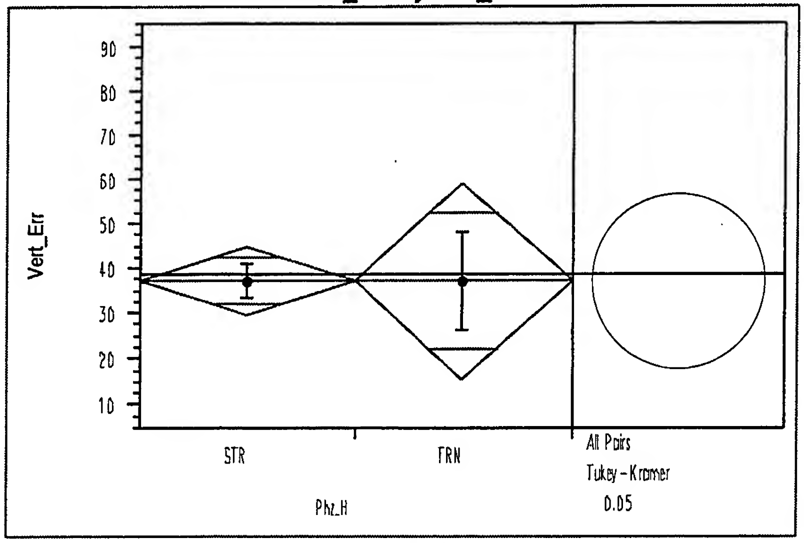
| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 2.3960 | 1 | 3678.4 | 0.1217 |

t-Test

1.5479

**Figure A.1- 115 Statistical Tests for Longitudinal Error and Horizontal Phase of Flight at Look Ahead Time 0 for Samples at Altitudes Above 18,000 Feet**

## Vert_Err By Phz_H




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 23358 | 38.3347 | 591.230 | 3.868 |
| TRN | 2790 | 42.5057 | 597.128 | 11.305 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | TRN | STR |
|---|---|---|
| TRN | 0.00000 | 4.17099 |
| STR | -4.17099 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96006

| Abs(Dif)-LSD | TRN | STR |
|---|---|---|
| TRN | -31.0601 | -19.0665 |
| STR | -19.0665 | -10.7346 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 23358 | 591.2304 | 159.2353 | 135.3072 |
| TRN | 2790 | 597.1281 | 173.5532 | 150.0385 |

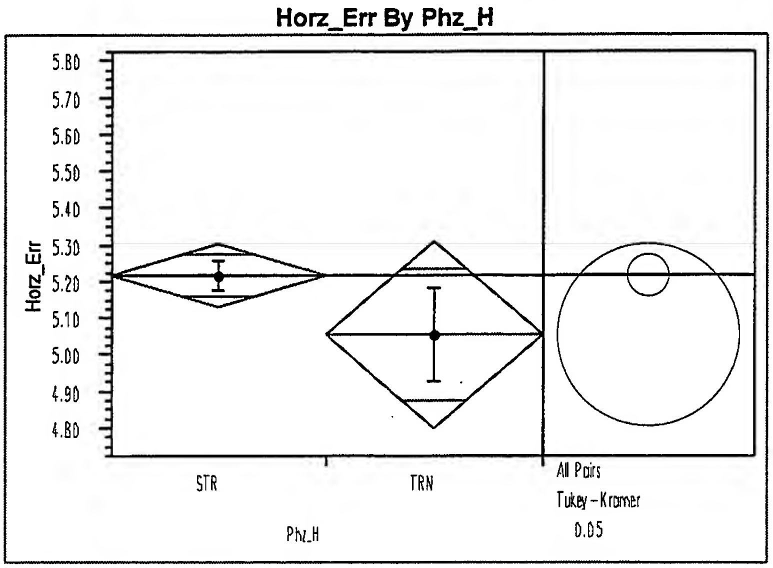
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 0.0008 | 1 | 26146 | 0.9776 |
| Brown-Forsythe | 1.6240 | 1 | 26146 | 0.2026 |
| Levene | 1.5748 | 1 | 26146 | 0.2095 |
| Bartlett | 0.4934 | 1 | ? | 0.4824 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 0.1219 | 1 | 3474.7 | 0.7270 |

| t-Test |
|---|
| 0.3491 |

**Figure A.1- 116 Statistical Tests for Vertical Error and Horizontal Phase of Flight at Look Ahead Time 0 for Samples at Altitudes Above 18,000 Feet**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 16318 | 5.23890 | 5.69627 | 0.04459 |
| TRN | 1892 | 5.05890 | 5.74944 | 0.13218 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | STR | TRN |
|---|---|---|
| STR | 0.000000 | 0.180003 |
| TRN | -0.18 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96010

| Abs(Dif)-LSD | STR | TRN |
|---|---|---|
| STR | -0.12373 | -0.09142 |
| TRN | -0.09142 | -0.36337 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 16318 | 5.696270 | 3.835836 | 3.501459 |
| TRN | 1892 | 5.749441 | 3.717368 | 3.372649 |

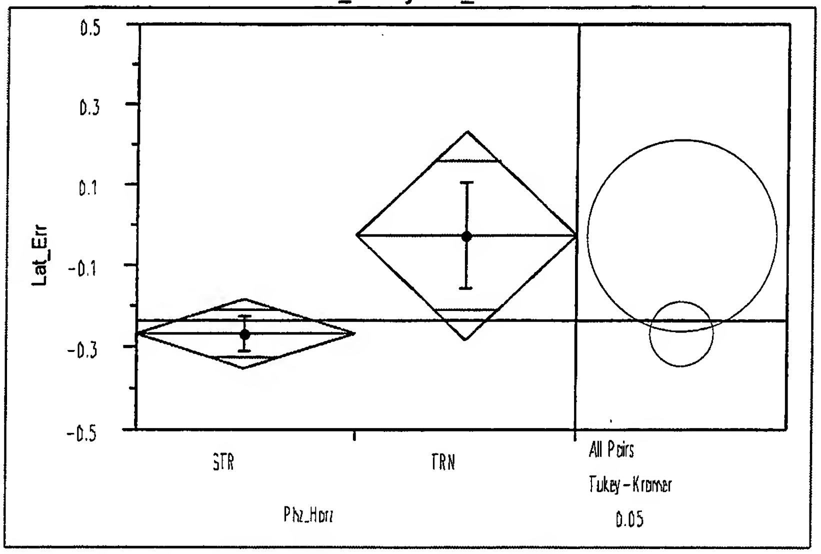
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 0.0153 | 1 | 18208 | 0.9016 |
| Brown-Forsythe | 1.1879 | 1 | 18208 | 0.2758 |
| Levene | 1.3302 | 1 | 18208 | 0.2488 |
| Bartlett | 0.2940 | 1 | ? | 0.5877 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 1.6650 | 1 | 2342.4 | 0.1971 |
| t-Test | | | |
| 1.2904 | | | |

**Figure A.1- 117 Statistical Tests for Horizontal Error and Horizontal Phase of Flight at Look Ahead Time 600 for Samples at Altitudes Above 18,000 Feet**

Lat_Err By Phz_Horz




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 16318 | -0.2597 | 5.82078 | 0.04557 |
| TRN | 1892 | -0.00098 | 5.77924 | 0.13286 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | TRN | STR |
|---|---|---|
| TRN | 0.000000 | 0.258717 |
| STR | -0.25872 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96010

| Abs(Dif)-LSD | TRN | STR |
|---|---|---|
| TRN | -0.37067 | -0.01817 |
| STR | -0.01817 | -0.12622 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 16318 | 5.820778 | 3.114442 | 3.078079 |
| TRN | 1892 | 5.779244 | 2.890671 | 2.890516 |

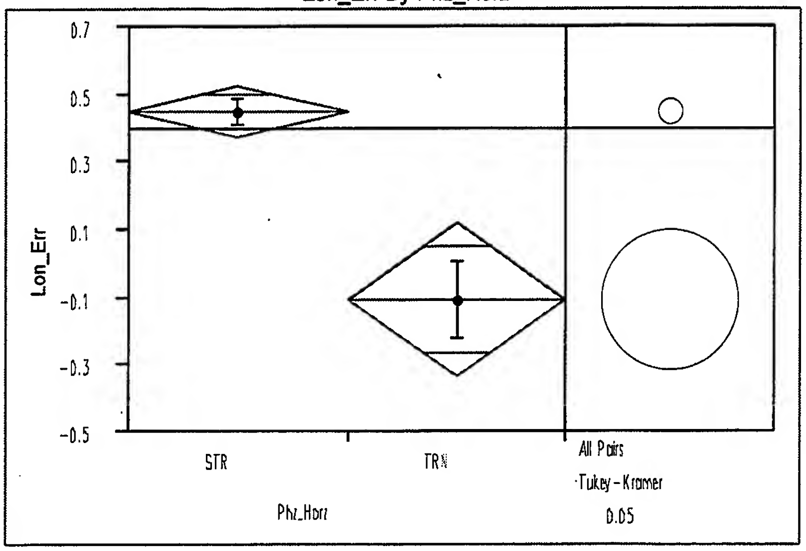
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 0.0169 | 1 | 18208 | 0.8967 |
| Brown-Forsythe | 2.4318 | 1 | 18208 | 0.1189 |
| Levene | 3.4979 | 1 | 18208 | 0.0615 |
| Bartlett | 0.1731 | 1 | ? | 0.6774 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 3.3926 | 1 | 2358.2 | 0.0656 |
| t-Test | | | |
| 1.8419 | | | |

**Figure A.1- 118 Statistical Tests for Lateral Error and Horizontal Phase of Flight at Look Ahead Time 600 for Samples at Altitudes Above 18,000 Feet**

Lon_Err By Phz_Horz




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 16318 | 0.456530 | 5.07326 | 0.03971 |
| TRN | 1892 | -0.08975 | 5.02537 | 0.11553 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | STR | TRN |
|---|---|---|
| STR | 0.000000 | 0.546280 |
| TRN | -0.54628 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96010

| Abs(Dif)-LSD | STR | TRN |
|---|---|---|
| STR | -0.10998 | 0.305012 |
| TRN | 0.305012 | -0.32299 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 16318 | 5.073258 | 3.236401 | 3.231738 |
| TRN | 1892 | 5.025372 | 3.323618 | 3.323467 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 0.0207 | 1 | 18208 | 0.8857 |
| Brown-Forsythe | 0.9378 | 1 | 18208 | 0.3329 |
| Levene | 0.8511 | 1 | 18208 | 0.3563 |
| Bartlett | 0.3032 | 1 | ? | 0.5819 |

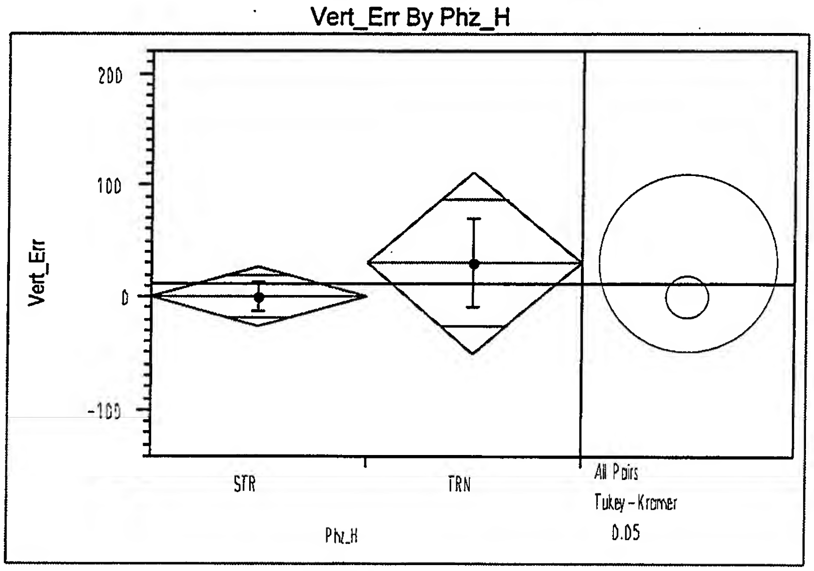
Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 19.9945 | 1 | 2360.5 | <.0001 |

t-Test

4.4715

**Figure A.1- 119 Statistical Tests for Longitudinal Error and Horizontal Phase of Flight at Look Ahead Time 600 for Samples at Altitudes Above 18,000 Feet**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 16318 | 10.0765 | 1820.98 | 14.255 |
| TRN | 1892 | 39.1177 | 1808.85 | 41.586 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | TRN | STR |
|---|---|---|
| TRN | 0.0000 | 29.0413 |
| STR | -29.0413 | 0.0000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96010

| Abs(Dif)-LSD | TRN | STR |
|---|---|---|
| TRN | -115.968 | -57.584 |
| STR | -57.584 | -39.488 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 16318 | 1820.979 | 777.3691 | 771.0343 |
| TRN | 1892 | 1808.851 | 800.4795 | 779.4070 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 0.0157 | 1 | 18208 | 0.9002 |
| Brown-Forsythe | 0.0438 | 1 | 18208 | 0.8343 |
| Levene | 0.3350 | 1 | 18208 | 0.5628 |
| Bartlett | 0.1508 | 1 | ? | 0.6978 |

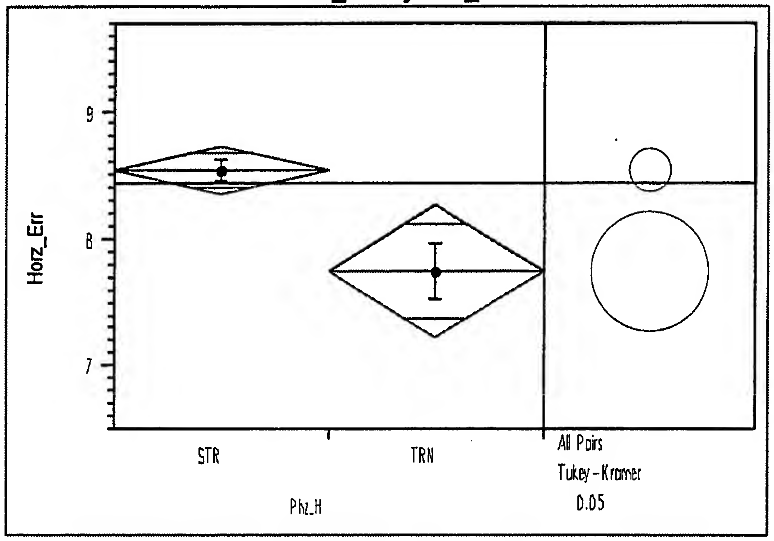
Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 0.4364 | 1 | 2357.7 | 0.5089 |

| t-Test |
|---|
| 0.6606 |

**Figure A.1- 120 Statistical Tests for Vertical Error and Horizontal Phase of Flight at Look Ahead Time 600 for Samples at Altitudes Above 18,000 Feet**

Horz_Err By Phz_H




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 9175 | 8.53584 | 9.51142 | 0.09930 |
| TRN | 1199 | 7.76842 | 7.64834 | 0.22088 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | STR | TRN |
|---|---|---|
| STR | 0.000000 | 0.767420 |
| TRN | -0.76742 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96019

| Abs(Dif)-LSD | STR | TRN |
|---|---|---|
| STR | -0.26959 | 0.206687 |
| TRN | 0.206687 | -0.74576 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 9175 | 9.511425 | 6.109777 | 5.633776 |
| TRN | 1199 | 7.648342 | 5.397756 | 4.964420 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 3.2807 | 1 | 10372 | 0.0701 |
| Brown-Forsythe | 7.4841 | 1 | 10372 | 0.0062 |
| Levene | 10.6699 | 1 | 10372 | 0.0011 |
| Bartlett | 90.0718 | 1 | ? | <.0001 |

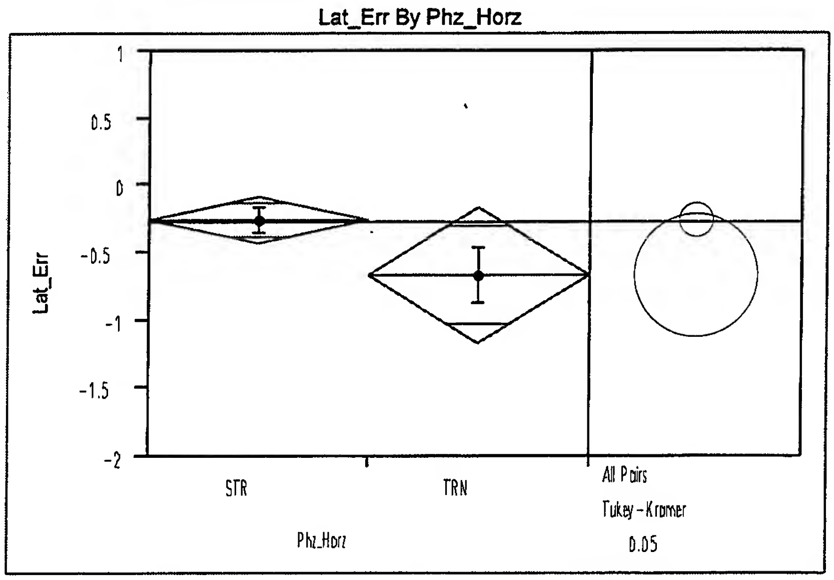
Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 10.0417 | 1 | 1722 | 0.0016 |

t-Test

3.1689

**Figure A.1- 121 Statistical Tests for Horizontal Error and Horizontal Phase of Flight at Look Ahead Time 1200 for Samples at Altitudes Above 18,000 Feet**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 9175 | -0.21317 | 9.38578 | 0.09799 |
| TRN | 1199 | -0.66354 | 7.40428 | 0.21383 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | STR | TRN |
|---|---|---|
| STR | 0.000000 | 0.450373 |
| TRN | -0.45037 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96019

| Abs(Dif)-LSD | STR | TRN |
|---|---|---|
| STR | -0.26564 | -0.10214 |
| TRN | -0.10214 | -0.73483 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 9175 | 9.385777 | 4.743009 | 4.714468 |
| TRN | 1199 | 7.404276 | 3.825791 | 3.672525 |

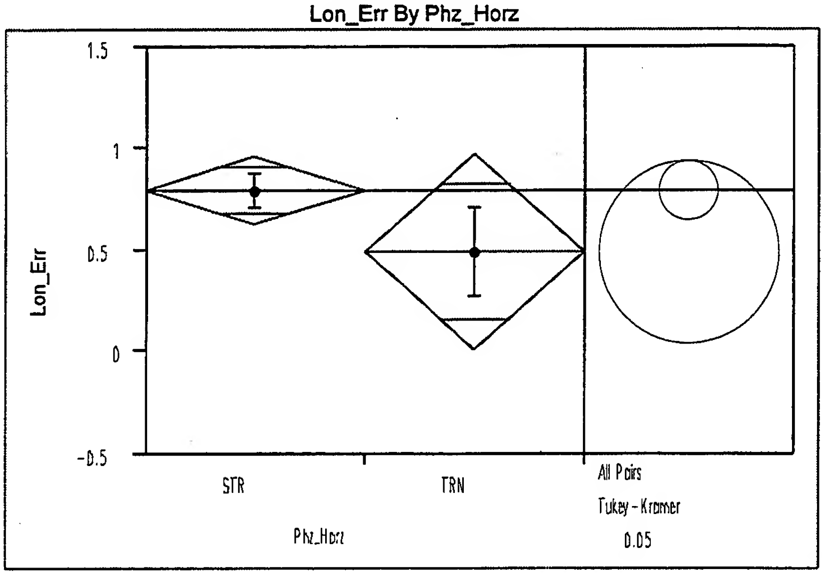
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 5.5623 | 1 | 10372 | 0.0184 |
| Brown-Forsythe | 18.2386 | 1 | 10372 | <.0001 |
| Levene | 14.2379 | 1 | 10372 | 0.0002 |
| Bartlett | 105.5457 | 1 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 3.6662 | 1 | 1743.9 | 0.0557 |

t-Test
1.9147

**Figure A.1- 122 Statistical Tests for Lateral Error and Horizontal Phase of Flight at Look Ahead Time 1200 for Samples at Altitudes Above 18,000 Feet**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 9175 | 0.835531 | 8.63130 | 0.09011 |
| TRN | 1199 | 0.513125 | 7.96043 | 0.22989 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | STR | TRN |
|---|---|---|
| STR | 0.000000 | 0.322406 |
| TRN | -0.32241 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96019

| Abs(Dif)-LSD | STR | TRN |
|---|---|---|
| STR | -0.24763 | -0.19265 |
| TRN | -0.19265 | -0.68502 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 9175 | 8.631296 | 5.547993 | 5.543110 |
| TRN | 1199 | 7.960427 | 5.580866 | 5.580622 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 1.1268 | 1 | 10372 | 0.2885 |
| Brown-Forsythe | 0.0351 | 1 | 10372 | 0.8514 |
| Levene | 0.0270 | 1 | 10372 | 0.8694 |
| Bartlett | 13.3068 | 1 | ? | 0.0003 |

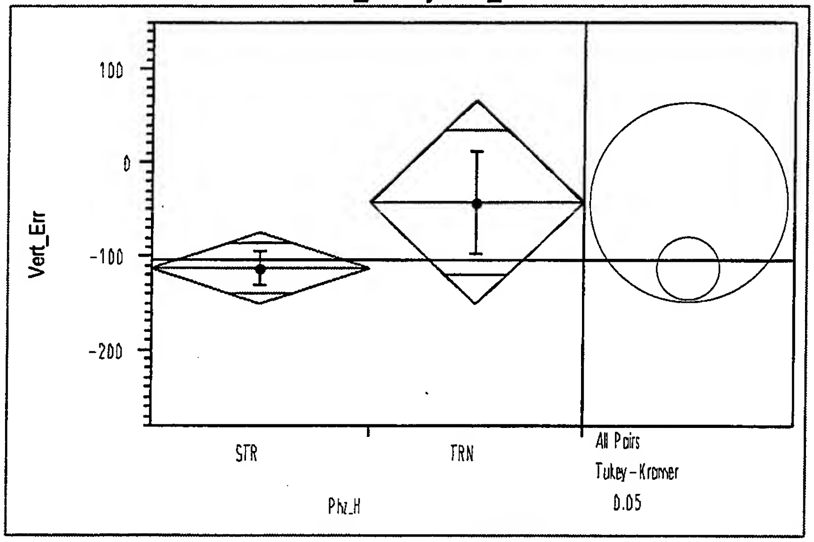
Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 1.7048 | 1 | 1589.5 | 0.1918 |

t-Test
1.3057

**Figure A.1- 123 Statistical Tests for Longitudinal Error and Horizontal Phase of Flight at Look Ahead Time 1200 for Samples at Altitudes Above 18,000 Feet**

Vert_Err By Phz_H




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 9175 | -111.926 | 1930.07 | 20.150 |
| TRN | 1199 | -35.298 | 1895.78 | 54.749 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | TRN | STR |
|---|---|---|
| TRN | 0.0000 | 76.6284 |
| STR | -76.6284 | 0.0000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96019

| Abs(Dif)-LSD | TRN | STR |
|---|---|---|
| TRN | -154.203 | -39.315 |
| STR | -39.315 | -55.744 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 9175 | 1930.066 | 836.1124 | 771.1156 |
| TRN | 1199 | 1895.776 | 838.4980 | 819.3713 |

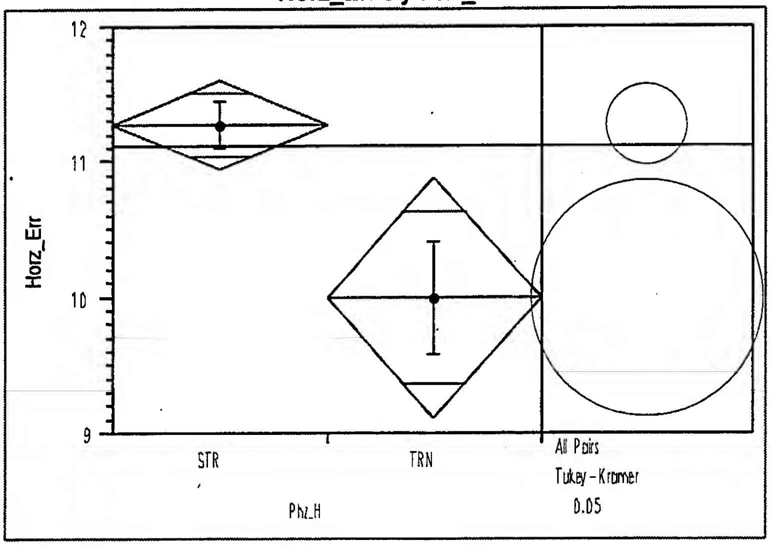
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 0.0248 | 1 | 10372 | 0.8750 |
| Brown-Forsythe | 0.7920 | 1 | 10372 | 0.3735 |
| Levene | 0.0020 | 1 | 10372 | 0.9643 |
| Bartlett | 0.6746 | 1 | ? | 0.4115 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 1.7253 | 1 | 1540.8 | 0.1892 |
| t-Test | | | |
| 1.3135 | | | |

**Figure A.1- 124 Statistical Tests for Vertical Error and Horizontal Phase of Flight at Look Ahead Time 1200 for Samples at Altitudes Above 18,000 Feet**

Horz_Err By Phz_H




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 4254 | 10.7846 | 11.7023 | 0.17942 |
| TRN | 637 | 9.5064 | 10.4089 | 0.41241 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | STR | TRN |
|---|---|---|
| STR | 0.00000 | 1.27821 |
| TRN | -1.27821 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96045

| Abs(Dif)-LSD | STR | TRN |
|---|---|---|
| STR | -0.49064 | 0.31687 |
| TRN | 0.31687 | -1.26792 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 4254 | 11.70232 | 7.510429 | 6.954786 |
| TRN | 637 | 10.40887 | 6.378097 | 5.888848 |

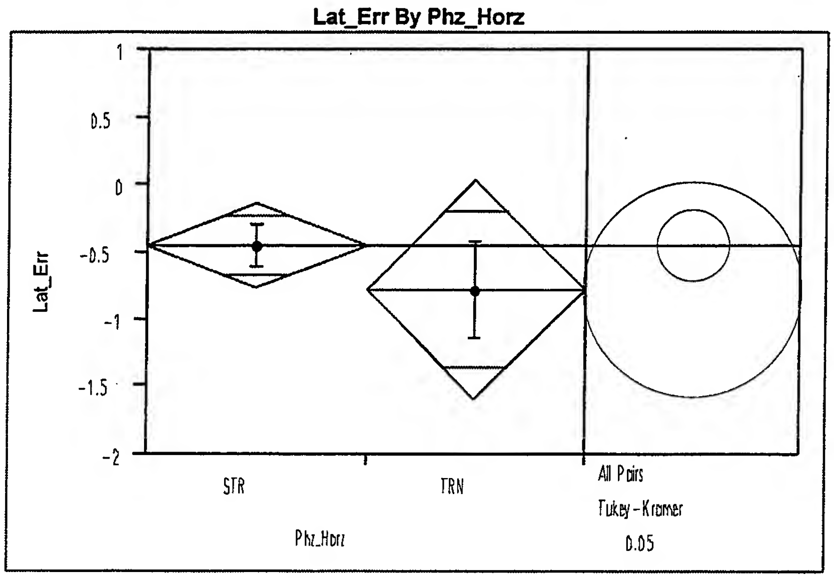
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 0.9388 | 1 | 4889 | 0.3326 |
| Brown-Forsythe | 6.4649 | 1 | 4889 | 0.0110 |
| Levene | 9.0099 | 1 | 4889 | 0.0027 |
| Bartlett | 14.3189 | 1 | ? | 0.0002 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 8.0771 | 1 | 894.74 | 0.0046 |

| t-Test |
|---|
| 2.8420 |

**Figure A.1- 125 Statistical Tests for Horizontal Error and Horizontal Phase of Flight at Look Ahead Time 1800 for Samples at Altitudes Above 18,000 Feet**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 4254 | -0.40004 | 10.9280 | 0.16755 |
| TRN | 637 | -0.73659 | 9.4788 | 0.37556 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | STR | TRN |
|---|---|---|
| STR | 0.000000 | 0.336548 |
| TRN | -0.33655 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96045

| Abs(Dif)-LSD | STR | TRN |
|---|---|---|
| STR | -0.45698 | -0.55885 |
| TRN | -0.55885 | -1.18095 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

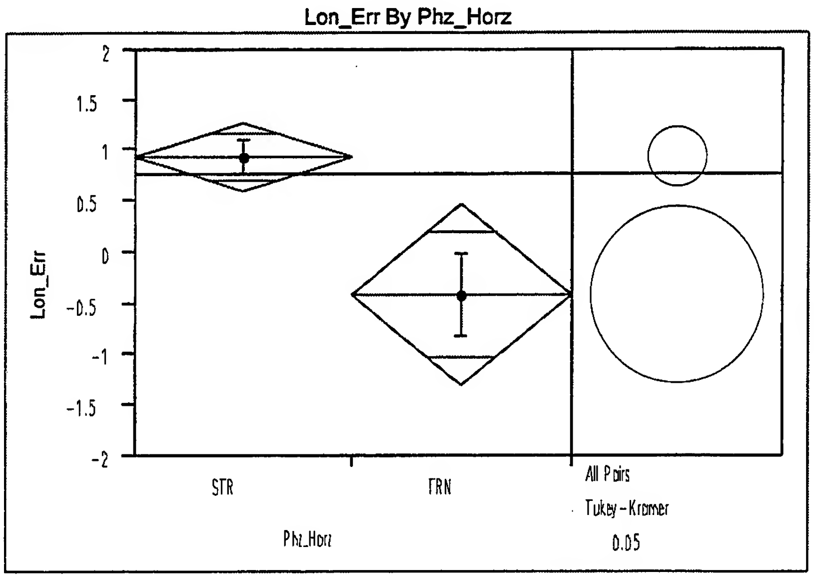
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 4254 | 10.92798 | 5.353029 | 5.267601 |
| TRN | 637 | 9.47882 | 4.043594 | 3.830462 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 1.0814 | 1 | 4889 | 0.2984 |
| Brown-Forsythe | 12.7507 | 1 | 4889 | 0.0004 |
| Levene | 10.7328 | 1 | 4889 | 0.0011 |
| Bartlett | 20.8636 | 1 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 0.6697 | 1 | 908.97 | 0.4134 |
| t-Test | | | |
| 0.8184 | | | |

**Figure A.1- 126 Statistical Tests for Lateral Error and Horizontal Phase of Flight at Look Ahead Time 1800 for Samples at Altitudes Above 18,000 Feet**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 4254 | 0.951593 | 11.5236 | 0.17668 |
| TRN | 637 | -0.39177 | 10.4074 | 0.41235 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | STR | TRN |
|---|---|---|
| STR | 0.00000 | 1.34336 |
| TRN | -1.34336 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96045

| Abs(Dif)-LSD | STR | TRN |
|---|---|---|
| STR | -0.48394 | 0.39516 |
| TRN | 0.39516 | -1.25060 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 4254 | 11.52359 | 7.627530 | 7.625923 |
| TRN | 637 | 10.40737 | 7.303754 | 7.303065 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 1.9631 | 1 | 4889 | 0.1612 |
| Brown-Forsythe | 0.8011 | 1 | 4889 | 0.3708 |
| Levene | 0.8063 | 1 | 4889 | 0.3693 |
| Bartlett | 10.9159 | 1 | ? | 0.0010 |

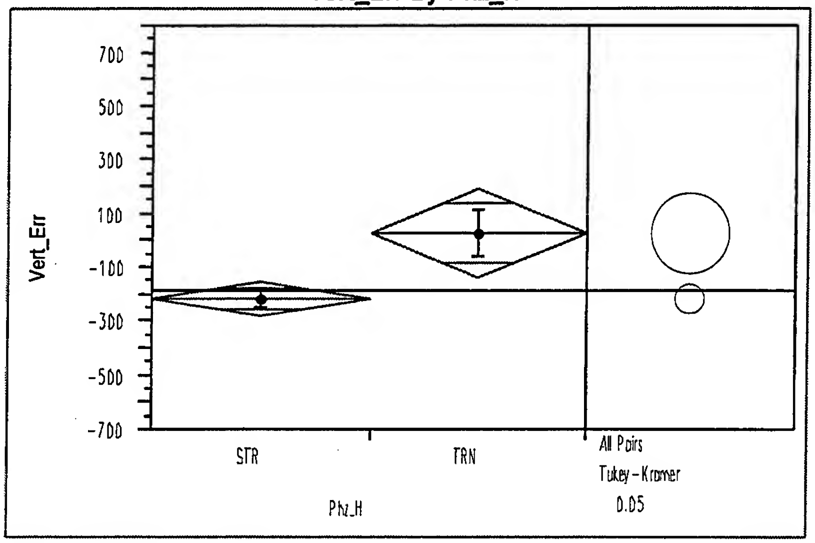
Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 8.9670 | 1 | 886.49 | 0.0028 |

t-Test
2.9945

**Figure A.1- 127 Statistical Tests for Longitudinal Error and Horizontal Phase of Flight at Look Ahead Time 1800 for Samples at Altitudes Above 18,000 Feet**

Vert_Err By Phz_H




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 4254 | -210.646 | 2127.36 | 32.617 |
| TRN | 637 | 23.332 | 2234.08 | 88.517 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | TRN | STR |
|---|---|---|
| TRN | 0.000 | 233.978 |
| STR | -233.978 | 0.000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96045

| Abs(Dif)-LSD | TRN | STR |
|---|---|---|
| TRN | -235.249 | 55.611 |
| STR | 55.611 | -91.033 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 4254 | 2127.360 | 1009.336 | 885.6140 |
| TRN | 637 | 2234.076 | 957.289 | 945.7591 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 0.1250 | 1 | 4889 | 0.7237 |
| Brown-Forsythe | 0.5238 | 1 | 4889 | 0.4692 |
| Levene | 0.4192 | 1 | 4889 | 0.5174 |
| Bartlett | 2.7141 | 1 | ? | 0.0995 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 6.1517 | 1 | 818.18 | 0.0133 |

| t-Test |
|---|
| 2.4803 |

**Figure A.1- 128 Statistical Tests for Vertical Error and Horizontal Phase of Flight at Look Ahead Time 1800 for Samples at Altitudes Above 18,000 Feet**

## *A.1.4 Vertical Phase of Flight Per Look Ahead Time*

### A.1.4.1 Summary Tables

| Look Ahead Time | 0 | | | 300 | | |
|---|---|---|---|---|---|---|
| Vertical Phase of Flight | Level | Ascent | Descent | Level | Ascent | Descent |
| Sample Quantity | 27915 | 4378 | 3635 | 24176 | 2150 | 3473 |
| Avg. Horz. Error | 1.19 | 1.21 | 1.35 | 2.95 | 4.71 | 3.71 |
| Stddev. Horz. Error | 1.04 | 0.88 | 1.51 | 3.25 | 3.9 | 3.76 |
| Max. Horz. Error | 42.39 | 11.19 | 16.91 | 84.31 | 50.76 | 63.15 |
| Min. Horz. Error | 0 | 0 | 0 | 0.01 | 0.02 | 0.02 |
| Avg. Lat. Error | -0.02 | -0.08 | 0.04 | -0.09 | -0.13 | -0.13 |
| Stddev. Lat. Error | 1.29 | 1.28 | 1.76 | 3.51 | 4.44 | 3.96 |
| Max. Lat. Error | 32.23 | 8.32 | 11.67 | 65.49 | 38.93 | 22.62 |
| Min. Lat. Error | -13.68 | -5.18 | -16 | -39.47 | -22.4 | -36.24 |
| Avg. Abs. Lat. Error | 0.84 | 0.93 | 1.02 | 1.88 | 2.66 | 2.23 |
| Stddev. Abs. Lat. Error | 0.97 | 0.88 | 1.44 | 2.97 | 3.56 | 3.28 |
| Max. Abs. Lat. Error | 32.23 | 8.32 | 16 | 65.49 | 38.93 | 36.24 |
| Min. Abs. Lat. Error | 0 | 0 | 0 | 0 | 0 | 0 |
| Avg. Long. Error | -0.02 | 0.07 | -0.08 | -0.01 | 1.45 | -0.11 |
| Stddev. Long. Error | 0.91 | 0.77 | 1 | 2.62 | 3.94 | 3.49 |
| Max. Long. Error | 11.93 | 3.58 | 9.33 | 25.52 | 20.1 | 19.67 |
| Min. Long. Error | -27.53 | -11.19 | -9.81 | -65.39 | -32.58 | -63.13 |
| Avg. Abs. Long. Error | 0.61 | 0.54 | 0.65 | 1.71 | 3.09 | 2.33 |
| Stddev. Abs. Long. Error | 0.68 | 0.55 | 0.77 | 1.98 | 2.84 | 2.6 |
| Max. Abs. Long. Error | 27.53 | 11.19 | 9.81 | 65.39 | 32.58 | 63.13 |
| Min. Abs. Long. Error | 0 | 0 | 0 | 0 | 0 | 0 |
| Avg. Vert. Error | 43.04 | 143.42 | -15.44 | -22.97 | 996.7 | -516.74 |
| Stddev. Vert. Error | 619.13 | 640.23 | 944.25 | 1140.53 | 2952.07 | 2644.55 |
| Max. Vert. Error | 36817 | 16745.34 | 7949 | 14714.2 | 14101 | 34817 |
| Min. Vert. Error | -6824.15 | -2010.37 | -4734 | -12244.5 | -10885.8 | -12626.9 |
| Avg. Abs. Vert. Error | 120.39 | 435.5 | 568.52 | 415.04 | 2271.07 | 2013.62 |
| Stddev. Abs. Vert. Error | 608.84 | 490.68 | 754.02 | 1062.58 | 2132.71 | 1790.23 |
| Max. Abs. Vert. Error | 36817 | 16745.34 | 7949 | 14714.2 | 14101 | 34817 |
| Min. Abs. Vert. Error | 0 | 0 | 0 | 0 | 0 | 0 |
| Avg. Slant Range Error | 1.19 | 1.21 | 1.36 | 2.95 | 4.75 | 3.76 |
| Stddev. Slant Range Error | 1.05 | 0.88 | 1.51 | 3.25 | 3.88 | 3.74 |
| Max. Slant Range Error | 42.39 | 11.52 | 16.91 | 84.34 | 50.76 | 63.15 |
| Min. Slant Range Error | 0 | 0 | 0 | 0.01 | 0.06 | 0.08 |

**Figure A.1- 129 Descriptive Statistics for Vertical Phase of Flight per Look Ahead Time for Samples at All Altitudes**

| Look Ahead Time | 600 | | | 900 | | |
|---|---|---|---|---|---|---|
| Vertical Phase of Flight | Level | Ascent | Descent | Level | Ascent | Descent |
| Sample Quantity | 20064 | 818 | 3082 | 15766 | 230 | 2533 |
| Avg. Horz. Error | 4.86 | 8.45 | 5.82 | 6.61 | 13.56 | 7.54 |
| Stddev. Horz. Error | 5.34 | 6.42 | 5.63 | 7.23 | 10.25 | 6.91 |
| Max. Horz. Error | 125.68 | 38.68 | 73.81 | 167.79 | 76.9 | 92.08 |
| Min. Horz. Error | 0.02 | 0.04 | 0.04 | 0.02 | 0.23 | 0.06 |
| Avg. Lat. Error | -0.21 | 0.25 | -0.03 | -0.27 | 0.5 | 0.09 |
| Stddev. Lat. Error | 5.41 | 6.76 | 5.19 | 7.03 | 8.87 | 6.47 |
| Max. Lat. Error | 97.45 | 29.34 | 34.75 | 129.48 | 43.07 | 64.16 |
| Min. Lat. Error | -61.74 | -28.48 | -37.37 | -94.55 | -27.26 | -43.4 |
| Avg. Abs. Lat. Error | 2.8 | 4.02 | 2.97 | 3.56 | 5.24 | 3.61 |
| Stddev. Abs. Lat. Error | 4.63 | 5.43 | 4.25 | 6.06 | 7.17 | 5.37 |
| Max. Abs. Lat. Error | 97.45 | 29.34 | 37.37 | 129.48 | 43.07 | 64.16 |
| Min. Abs. Lat. Error | 0 | 0 | 0 | 0 | 0.01 | 0 |
| Avg. Long. Error | 0.2 | 4.1 | 0.45 | 0.43 | 7.06 | 0.51 |
| Stddev. Long. Error | 4.78 | 7.08 | 6.2 | 6.81 | 12.68 | 7.91 |
| Max. Long. Error | 91.73 | 31.85 | 73.8 | 94.25 | 39.37 | 66.05 |
| Min. Long. Error | -79.36 | -32.6 | -42.72 | -106.71 | -76.71 | -59.55 |
| Avg. Abs. Long. Error | 3.07 | 6.18 | 4.07 | 4.37 | 10.74 | 5.45 |
| Stddev. Abs. Long. Error | 3.67 | 5.37 | 4.69 | 5.24 | 9.75 | 5.75 |
| Max. Abs. Long. Error | 91.73 | 32.6 | 73.8 | 106.71 | 76.71 | 66.05 |
| Min. Abs. Long. Error | 0 | 0.01 | 0 | 0 | 0.07 | 0 |
| Avg. Vert. Error | -93.56 | 1322.7 | -726.17 | -120.46 | 810.29 | -666.06 |
| Stddev. Vert. Error | 1551.14 | 3799.44 | 3080.04 | 1721.64 | 3518.2 | 3089.16 |
| Max. Vert. Error | 20728.9 | 20033 | 28933 | 30746.5 | 20083 | 22083 |
| Min. Vert. Error | -15373.8 | -9233 | -14433.7 | -16419.3 | -6400 | -15260.4 |
| Avg. Abs. Vert. Error | 610.27 | 2963.65 | 2377.63 | 691.68 | 2700.92 | 2367.68 |
| Stddev. Abs. Vert. Error | 1429.11 | 2719.09 | 2087.87 | 1581.17 | 2389.62 | 2092.51 |
| Max. Abs. Vert. Error | 20728.9 | 20033 | 28933 | 30746.5 | 20083 | 22083 |
| Min. Abs. Vert. Error | 0 | 0 | 0 | 0 | 16.39 | 0 |
| Avg. Slant Range Error | 4.87 | 8.49 | 5.86 | 6.62 | 13.58 | 7.58 |
| Stddev. Slant Range Error | 5.34 | 6.4 | 5.61 | 7.23 | 10.24 | 6.89 |
| Max. Slant Range Error | 125.72 | 38.68 | 73.82 | 167.86 | 76.9 | 92.08 |
| Min. Slant Range Error | 0.02 | 0.17 | 0.15 | 0.03 | 0.29 | 0.11 |

**Figure A.1- 130 Descriptive Statistics for Vertical Phase of Flight per Look Ahead Time for Samples at All Altitudes**

| Look Ahead Time | 1200 | | | 1500 | | |
|---|---|---|---|---|---|---|
| Vertical Phase of Flight | Level | Ascent | Descent | Level | Ascent | Descent |
| Sample Quantity | 11878 | 67 | 1891 | 8394 | 22 | 1262 |
| Avg. Horz. Error | 8.14 | 15.88 | 8.65 | 9.33 | 13.14 | 9.47 |
| Stddev. Horz. Error | 9 | 13.46 | 7.81 | 10.22 | 12.97 | 9.13 |
| Max. Horz. Error | 173.62 | 62.8 | 68.48 | 156.35 | 50.19 | 72.96 |
| Min. Horz. Error | 0.02 | 0.72 | 0.04 | 0.01 | 3.11 | 0.11 |
| Avg. Lat. Error | -0.32 | 0.62 | 0.41 | -0.42 | -3.78 | 1 |
| Stddev. Lat. Error | 8.6 | 9.9 | 6.98 | 9.63 | 13.25 | 8.33 |
| Max. Lat. Error | 134.87 | 29.67 | 53.61 | 120.34 | 16.99 | 65.64 |
| Min. Lat. Error | -124.94 | -46.11 | -66.12 | -143.49 | -40.37 | -70.8 |
| Avg. Abs. Lat. Error | 4.2 | 5.21 | 3.85 | 4.6 | 7.16 | 4.37 |
| Stddev. Abs. Lat. Error | 7.51 | 8.42 | 5.84 | 8.47 | 11.69 | 7.16 |
| Max. Abs. Lat. Error | 134.87 | 46.11 | 66.12 | 143.49 | 40.37 | 70.8 |
| Min. Abs. Lat. Error | 0 | 0.02 | 0 | 0 | 0.03 | 0 |
| Avg. Long. Error | 0.56 | 6.09 | 1.33 | 0.68 | 2.87 | 1.48 |
| Stddev. Long. Error | 8.53 | 17.36 | 9.23 | 9.91 | 12.25 | 10.02 |
| Max. Long. Error | 96.16 | 39.2 | 48.6 | 97.63 | 27.67 | 44.17 |
| Min. Long. Error | -109.33 | -62.47 | -60.41 | -99.82 | -32.7 | -56.49 |
| Avg. Abs. Long. Error | 5.56 | 13.48 | 6.52 | 6.59 | 9.14 | 6.95 |
| Stddev. Abs. Long. Error | 6.5 | 12.42 | 6.66 | 7.44 | 8.45 | 7.37 |
| Max. Abs. Long. Error | 109.33 | 62.47 | 60.41 | 99.82 | 32.7 | 56.49 |
| Min. Abs. Long. Error | 0 | 0.52 | 0 | 0 | 0.51 | 0.01 |
| Avg. Vert. Error | -125.54 | 366.59 | -692.95 | -167.37 | 1720.92 | -1015.01 |
| Stddev. Vert. Error | 1861.58 | 3022.95 | 3212.21 | 1966.21 | 5173.23 | 3302.33 |
| Max. Vert. Error | 37473.73 | 15524.09 | 15561.15 | 38907.87 | 20104.51 | 11333 |
| Min. Vert. Error | -15900 | -5733 | -13410.8 | -15900 | -2899 | -17219.3 |
| Avg. Abs. Vert. Error | 744.35 | 1904.83 | 2500.94 | 822 | 2641.13 | 2658.72 |
| Stddev. Abs. Vert. Error | 1710.89 | 2364.59 | 2130.9 | 1793.94 | 4749.44 | 2205 |
| Max. Abs. Vert. Error | 37473.73 | 15524.09 | 15561.15 | 38907.87 | 20104.51 | 17219.3 |
| Min. Abs. Vert. Error | 0 | 0 | 0 | 0 | 182.91 | 0 |
| Avg. Slant Range Error | 8.15 | 15.89 | 8.69 | 9.34 | 13.16 | 9.51 |
| Stddev. Slant Range Error | 8.99 | 13.46 | 7.79 | 10.22 | 12.98 | 9.11 |
| Max. Slant Range Error | 173.7 | 62.8 | 68.48 | 156.48 | 50.3 | 72.96 |
| Min. Slant Range Error | 0.02 | 0.77 | 0.15 | 0.01 | 3.11 | 0.16 |

**Figure A.1- 131 Descriptive Statistics for Vertical Phase of Flight per Look Ahead Time for Samples at All Altitudes**

| Look Ahead Time | 1800 | | |
|---|---|---|---|
| Vertical Phase of Flight | Level | Ascent | Descent |
| Sample Quantity | 5652 | 11 | 781 |
| Avg. Horz. Error | 10.23 | 8.6 | 9.71 |
| Stddev. Horz. Error | 11.1 | 5.07 | 9.34 |
| Max. Horz. Error | 169.84 | 20.52 | 72.73 |
| Min. Horz. Error | 0.04 | 3.89 | 0.19 |
| Avg. Lat. Error | -0.45 | -0.67 | 1.44 |
| Stddev. Lat. Error | 10.24 | 4.54 | 8.53 |
| Max. Lat. Error | 117.09 | 5.05 | 72.43 |
| Min. Lat. Error | -155.99 | -13.55 | -30.86 |
| Avg. Abs. Lat. Error | 4.8 | 1.99 | 4.35 |
| Stddev. Abs. Lat. Error | 9.05 | 4.09 | 7.48 |
| Max. Abs. Lat. Error | 155.99 | 13.55 | 72.43 |
| Min. Abs. Lat. Error | 0 | 0.07 | 0 |
| Avg. Long. Error | 0.79 | -2.91 | 1.57 |
| Stddev. Long. Error | 11.06 | 8.75 | 10.22 |
| Max. Long. Error | 98.01 | 7.18 | 41.28 |
| Min. Long. Error | -78.53 | -20.51 | -62.08 |
| Avg. Abs. Long. Error | 7.44 | 7.64 | 7.31 |
| Stddev. Abs. Long. Error | 8.23 | 4.66 | 7.3 |
| Max. Abs. Long. Error | 98.01 | 20.51 | 62.08 |
| Min. Abs. Long. Error | 0 | 2.78 | 0 |
| Avg. Vert. Error | -220.69 | 2367.53 | -1135.5 |
| Stddev. Vert. Error | 2072.25 | 4803.94 | 3374.12 |
| Max. Vert. Error | 31668.16 | 16540.79 | 11033 |
| Min. Vert. Error | -15800 | -200 | -12044.6 |
| Avg. Abs. Vert. Error | 868.83 | 2403.89 | 2750.38 |
| Stddev. Abs. Vert. Error | 1894.19 | 4784.03 | 2258.63 |
| Max. Abs. Vert. Error | 31668.16 | 16540.79 | 12044.58 |
| Min. Abs. Vert. Error | 0 | 0 | 3.91 |
| Avg. Slant Range Error | 10.24 | 8.62 | 9.75 |
| Stddev. Slant Range Error | 11.1 | 5.1 | 9.32 |
| Max. Slant Range Error | 169.84 | 20.52 | 72.73 |
| Min. Slant Range Error | 0.04 | 3.89 | 0.37 |

**Figure A.1- 132 Descriptive Statistics for Vertical Phase of Flight per Look Ahead Time for Samples at All Altitudes**

| Look Ahead Time | 0 | | | 300 | | |
|---|---|---|---|---|---|---|
| Vertical Phase of Flight | Level | Ascent | Descent | Level | Ascent | Descent |
| Sample Quantity | 21791 | 2345 | 2012 | 18964 | 1673 | 1863 |
| Avg. Horz. Error | 1.14 | 1.15 | 1.04 | 3 | 4.78 | 3.54 |
| Stddev. Horz. Error | 0.96 | 0.87 | 0.78 | 3.42 | 3.98 | 4 |
| Max. Horz. Error | 42.39 | 11.19 | 4.68 | 84.31 | 50.76 | 63.15 |
| Min. Horz. Error | 0 | 0 | 0 | 0.01 | 0.02 | 0.02 |
| Avg. Lat. Error | -0.02 | -0.08 | 0 | -0.11 | -0.13 | -0.29 |
| Stddev. Lat. Error | 1.21 | 1.21 | 1.11 | 3.7 | 4.52 | 4.1 |
| Max. Lat. Error | 32.23 | 8.32 | 4.27 | 65.49 | 38.93 | 19.22 |
| Min. Lat. Error | -6.04 | -5.18 | -4.5 | -39.47 | -22.4 | -36.24 |
| Avg. Abs. Lat. Error | 0.8 | 0.86 | 0.75 | 1.95 | 2.6 | 2.21 |
| Stddev. Abs. Lat. Error | 0.9 | 0.86 | 0.82 | 3.15 | 3.69 | 3.47 |
| Max. Abs. Lat. Error | 32.23 | 8.32 | 4.5 | 65.49 | 38.93 | 36.24 |
| Min. Abs. Lat. Error | 0 | 0 | 0 | 0 | 0 | 0 |
| Avg. Long. Error | -0.03 | 0.09 | -0.05 | 0 | 1.72 | 0 |
| Stddev. Long. Error | 0.88 | 0.77 | 0.68 | 2.64 | 3.92 | 3.41 |
| Max. Long. Error | 11.93 | 3.58 | 2.53 | 25.52 | 20.1 | 19.67 |
| Min. Long. Error | -27.53 | -11.19 | -2.81 | -65.39 | -32.58 | -63.13 |
| Avg. Abs. Long. Error | 0.6 | 0.55 | 0.53 | 1.7 | 3.21 | 2.13 |
| Stddev. Abs. Long. Error | 0.65 | 0.54 | 0.44 | 2.02 | 2.83 | 2.66 |
| Max. Abs. Long. Error | 27.53 | 11.19 | 2.81 | 65.39 | 32.58 | 63.13 |
| Min. Abs. Long. Error | 0 | 0 | 0 | 0 | 0 | 0 |
| Avg. Vert. Error | 33.86 | 164.9 | -54.94 | -0.98 | 926.65 | -102.63 |
| Stddev. Vert. Error | 582.1 | 689.82 | 548.35 | 1028.54 | 2786.63 | 2659.6 |
| Max. Vert. Error | 36817 | 16745.34 | 1699.79 | 14714.2 | 14101 | 34817 |
| Min. Vert. Error | -2800 | -1515.37 | -2264.79 | -8000 | -10304.6 | -9892.71 |
| Avg. Abs. Vert. Error | 79.21 | 436.46 | 412.27 | 334.12 | 2073.49 | 1944.84 |
| Stddev. Abs. Vert. Error | 577.68 | 558.99 | 365.59 | 972.76 | 2079.08 | 1816.48 |
| Max. Abs. Vert. Error | 36817 | 16745.34 | 2264.79 | 14714.2 | 14101 | 34817 |
| Min. Abs. Vert. Error | 0 | 0 | 0 | 0 | 0 | 0 |
| Avg. Slant Range Error | 1.15 | 1.16 | 1.05 | 3.01 | 4.82 | 3.6 |
| Stddev. Slant Range Error | 0.97 | 0.87 | 0.78 | 3.41 | 3.97 | 3.97 |
| Max. Slant Range Error | 42.39 | 11.52 | 4.69 | 84.34 | 50.76 | 63.15 |
| Min. Slant Range Error | 0 | 0 | 0 | 0.01 | 0.06 | 0.08 |

**Figure A.1- 133 Descriptive Statistics for Vertical Phase of Flight per Look Ahead Time for Samples at Altitudes Above 18,000 Feet**

| Look Ahead Time | 600 | | | 900 | | |
|---|---|---|---|---|---|---|
| Vertical Phase of Flight | Level | Ascent | Descent | Level | Ascent | Descent |
| Sample Quantity | 15821 | 790 | 1599 | 12478 | 224 | 1270 |
| Avg. Horz. Error | 5.01 | 8.5 | 5.64 | 6.83 | 13.62 | 7.33 |
| Stddev. Horz. Error | 5.61 | 6.36 | 5.71 | 7.57 | 9.98 | 7.46 |
| Max. Horz. Error | 125.68 | 38.68 | 51.38 | 167.79 | 76.9 | 92.08 |
| Min. Horz. Error | 0.02 | 0.04 | 0.04 | 0.03 | 0.23 | 0.06 |
| Avg. Lat. Error | -0.26 | 0.23 | -0.19 | -0.34 | 0.44 | 0.24 |
| Stddev. Lat. Error | 5.77 | 6.74 | 5.74 | 7.57 | 8.98 | 7.44 |
| Max. Lat. Error | 97.45 | 29.34 | 34.75 | 129.48 | 43.07 | 64.16 |
| Min. Lat. Error | -61.74 | -28.48 | -37.37 | -94.55 | -27.26 | -43.4 |
| Avg. Abs. Lat. Error | 3 | 4.01 | 3.17 | 3.87 | 5.31 | 4.07 |
| Stddev. Abs. Lat. Error | 4.94 | 5.42 | 4.78 | 6.51 | 7.25 | 6.23 |
| Max. Abs. Lat. Error | 97.45 | 29.34 | 37.37 | 129.48 | 43.07 | 64.16 |
| Min. Abs. Lat. Error | 0 | 0 | 0 | 0 | 0.01 | 0 |
| Avg. Long. Error | 0.22 | 4.27 | 0.28 | 0.45 | 7.49 | 0.28 |
| Stddev. Long. Error | 4.82 | 7.01 | 5.61 | 6.81 | 12.2 | 7.35 |
| Max. Long. Error | 91.73 | 31.85 | 25.54 | 94.25 | 39.37 | 66.05 |
| Min. Long. Error | -79.36 | -22.09 | -35.26 | -106.71 | -76.71 | -59.55 |
| Avg. Abs. Long. Error | 3.05 | 6.25 | 3.7 | 4.35 | 10.76 | 4.75 |
| Stddev. Abs. Long. Error | 3.73 | 5.32 | 4.22 | 5.26 | 9.43 | 5.61 |
| Max. Abs. Long. Error | 91.73 | 31.85 | 35.26 | 106.71 | 76.71 | 66.05 |
| Min. Abs. Long. Error | 0 | 0.01 | 0 | 0 | 0.07 | 0 |
| Avg. Vert. Error | -20.23 | 1329.85 | -307.77 | -29.38 | 840.91 | -329.29 |
| Stddev. Vert. Error | 1426.57 | 3826.34 | 3063.43 | 1594.72 | 3546.01 | 3215.15 |
| Max. Vert. Error | 20728.9 | 20033 | 28933 | 30746.5 | 20083 | 22083 |
| Min. Vert. Error | -10000 | -9233 | -10552 | -10700 | -6400 | -9797.11 |
| Avg. Abs. Vert. Error | 507.3 | 2980.59 | 2298.72 | 579.34 | 2736.66 | 2396.95 |
| Stddev. Abs. Vert. Error | 1333.46 | 2741.62 | 2047.42 | 1486.05 | 2400.32 | 2166.98 |
| Max. Abs. Vert. Error | 20728.9 | 20033 | 28933 | 30746.5 | 20083 | 22083 |
| Min. Abs. Vert. Error | 0 | 0 | 0 | 0 | 16.39 | 0 |
| Avg. Slant Range Error | 5.02 | 8.54 | 5.69 | 6.84 | 13.64 | 7.38 |
| Stddev. Slant Range Error | 5.61 | 6.34 | 5.68 | 7.56 | 9.97 | 7.44 |
| Max. Slant Range Error | 125.72 | 38.68 | 51.38 | 167.86 | 76.9 | 92.08 |
| Min. Slant Range Error | 0.02 | 0.29 | 0.15 | 0.03 | 0.29 | 0.11 |

**Figure A.1- 134 Descriptive Statistics for Vertical Phase of Flight per Look Ahead Time for Samples at Altitudes Above 18,000 Feet**

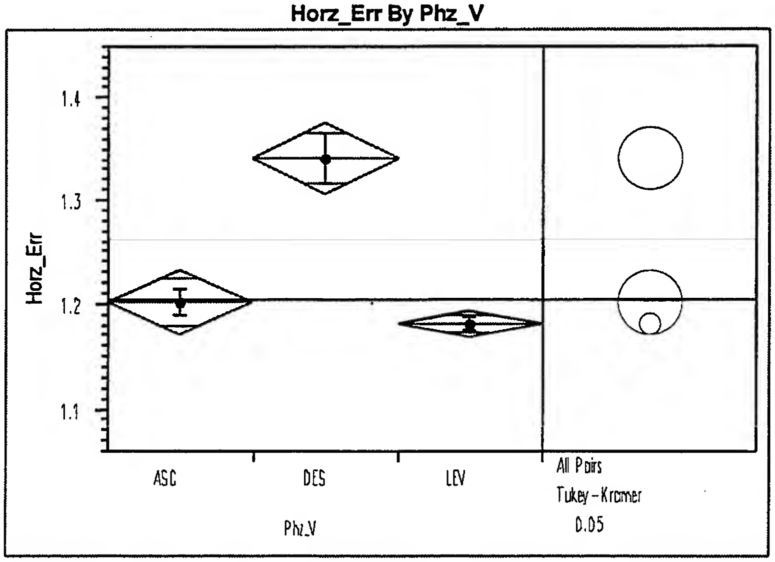
| Look Ahead Time | 1200 | | | 1500 | | |
|---|---|---|---|---|---|---|
| Vertical Phase of Flight | Level | Ascent | Descent | Level | Ascent | Descent |
| Sample Quantity | 9360 | 60 | 954 | 6627 | 20 | 660 |
| Avg. Horz. Error | 8.43 | 15.11 | 8.16 | 9.71 | 13.99 | 8.85 |
| Stddev. Horz. Error | 9.41 | 11.15 | 8.11 | 10.76 | 13.33 | 9.05 |
| Max. Horz. Error | 173.62 | 49.91 | 68.48 | 156.35 | 50.19 | 72.96 |
| Min. Horz. Error | 0.02 | 0.72 | 0.04 | 0.01 | 3.11 | 0.11 |
| Avg. Lat. Error | -0.36 | 0.54 | 0.64 | -0.52 | -4.56 | 1.15 |
| Stddev. Lat. Error | 9.29 | 10.37 | 7.86 | 10.37 | 13.67 | 8.62 |
| Max. Lat. Error | 134.87 | 29.67 | 53.61 | 120.34 | 16.99 | 65.64 |
| Min. Lat. Error | -124.94 | -46.11 | -66.12 | -143.49 | -40.37 | -70.8 |
| Avg. Abs. Lat. Error | 4.62 | 5.41 | 4.28 | 5.02 | 7.47 | 4.51 |
| Stddev. Abs. Lat. Error | 8.07 | 8.83 | 6.62 | 9.09 | 12.25 | 7.43 |
| Max. Abs. Lat. Error | 134.87 | 46.11 | 66.12 | 143.49 | 40.37 | 70.8 |
| Min. Abs. Lat. Error | 0 | 0.02 | 0 | 0 | 0.03 | 0 |
| Avg. Long. Error | 0.7 | 8.99 | 1.25 | 0.8 | 3.38 | 1.48 |
| Stddev. Long. Error | 8.52 | 12.91 | 8.29 | 10.08 | 12.77 | 9.09 |
| Max. Long. Error | 96.16 | 39.2 | 39.23 | 97.63 | 27.67 | 44.17 |
| Min. Long. Error | -109.33 | -19.1 | -60.41 | -99.82 | -32.7 | -56.49 |
| Avg. Abs. Long. Error | 5.52 | 12.59 | 5.57 | 6.66 | 9.83 | 6.14 |
| Stddev. Abs. Long. Error | 6.53 | 9.36 | 6.26 | 7.61 | 8.56 | 6.85 |
| Max. Abs. Long. Error | 109.33 | 39.2 | 60.41 | 99.82 | 32.7 | 56.49 |
| Min. Abs. Long. Error | 0 | 0.52 | 0 | 0 | 0.51 | 0.03 |
| Avg. Vert. Error | -57.6 | 393.25 | -580.42 | -103.97 | 1828.02 | -883.58 |
| Stddev. Vert. Error | 1735.54 | 3155.29 | 3150.19 | 1829.04 | 5424.51 | 3239.87 |
| Max. Vert. Error | 37473.73 | 15524.09 | 15561.15 | 38907.87 | 20104.51 | 11333 |
| Min. Vert. Error | -8230.95 | -5733 | -10485.7 | -8330.24 | -2899 | -9483.61 |
| Avg. Abs. Vert. Error | 603.38 | 1986.48 | 2401 | 663.35 | 2840.24 | 2547.37 |
| Stddev. Abs. Vert. Error | 1628.28 | 2469.84 | 2118.99 | 1707.66 | 4944.82 | 2186.27 |
| Max. Abs. Vert. Error | 37473.73 | 15524.09 | 15561.15 | 38907.87 | 20104.51 | 11333 |
| Min. Abs. Vert. Error | 0 | 0 | 0 | 0 | 182.91 | 0 |
| Avg. Slant Range Error | 8.44 | 15.13 | 8.2 | 9.72 | 14.02 | 8.89 |
| Stddev. Slant Range Error | 9.4 | 11.14 | 8.08 | 10.76 | 13.33 | 9.02 |
| Max. Slant Range Error | 173.7 | 49.91 | 68.48 | 156.48 | 50.3 | 72.96 |
| Min. Slant Range Error | 0.02 | 0.77 | 0.15 | 0.01 | 3.11 | 0.3 |

**Figure A.1- 135 Descriptive Statistics for Vertical Phase of Flight per Look Ahead Time for Samples at Altitudes Above 18,000 Feet**

| Look Ahead Time | 1800 | | |
|---|---|---|---|
| Vertical Phase of Flight | Level | Ascent | Descent |
| Sample Quantity | 4446 | 10 | 435 |
| Avg. Horz. Error | 10.81 | 8.88 | 8.69 |
| Stddev. Horz. Error | 11.8 | 5.25 | 8.45 |
| Max. Horz. Error | 169.84 | 20.52 | 62.23 |
| Min. Horz. Error | 0.04 | 3.89 | 0.19 |
| Avg. Lat. Error | -0.6 | -1.24 | 1.16 |
| Stddev. Lat. Error | 11.01 | 4.35 | 7.53 |
| Max. Lat. Error | 117.09 | 0.75 | 53.61 |
| Min. Lat. Error | -155.99 | -13.55 | -30.86 |
| Avg. Abs. Lat. Error | 5.21 | 1.69 | 3.84 |
| Stddev. Abs. Lat. Error | 9.72 | 4.18 | 6.58 |
| Max. Abs. Lat. Error | 155.99 | 13.55 | 53.61 |
| Min. Abs. Lat. Error | 0 | 0.07 | 0 |
| Avg. Long. Error | 0.81 | -2.93 | 0.55 |
| Stddev. Long. Error | 11.57 | 9.22 | 9.42 |
| Max. Long. Error | 98.01 | 7.18 | 41.28 |
| Min. Long. Error | -78.53 | -20.51 | -62.08 |
| Avg. Abs. Long. Error | 7.73 | 8.12 | 6.44 |
| Stddev. Abs. Long. Error | 8.65 | 4.61 | 6.89 |
| Max. Abs. Long. Error | 98.01 | 20.51 | 62.08 |
| Min. Abs. Long. Error | 0 | 3.88 | 0 |
| Avg. Vert. Error | -116.41 | 2414.28 | -891.51 |
| Stddev. Vert. Error | 1966.69 | 5061.16 | 3299.07 |
| Max. Vert. Error | 31668.16 | 16540.79 | 11033 |
| Min. Vert. Error | -8050.02 | -200 | -10550 |
| Avg. Abs. Vert. Error | 721.23 | 2454.28 | 2617.76 |
| Stddev. Abs. Vert. Error | 1833.34 | 5039.74 | 2193.63 |
| Max. Abs. Vert. Error | 31668.16 | 16540.79 | 11033 |
| Min. Abs. Vert. Error | 0 | 0 | 3.91 |
| Avg. Slant Range Error | 10.82 | 8.91 | 8.73 |
| Stddev. Slant Range Error | 11.8 | 5.28 | 8.43 |
| Max. Slant Range Error | 169.84 | 20.52 | 62.25 |
| Min. Slant Range Error | 0.04 | 3.89 | 0.37 |

**Figure A.1- 136 Descriptive Statistics for Vertical Phase of Flight per Look Ahead Time for Samples at Altitudes Above 18,000 Feet**

## A.1.4.2 Statistical Tests




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 4378 | 1.20749 | 0.88352 | 0.01335 |
| DES | 3635 | 1.34907 | 1.51234 | 0.02508 |
| LEV | 27915 | 1.18559 | 1.04348 | 0.00625 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | DES | ASC | LEV |
|---|---|---|---|
| DES | 0.000000 | 0.141582 | 0.163481 |
| ASC | -0.14158 | 0.000000 | 0.021898 |
| LEV | -0.16348 | -0.0219 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34380

| Abs(Dif)-LSD | DES | ASC | LEV |
|---|---|---|---|
| DES | -0.05953 | 0.084634 | 0.118729 |
| ASC | 0.084634 | -0.05424 | -0.01936 |
| LEV | 0.118729 | -0.01936 | -0.02148 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 4378 | 0.883522 | 0.6833410 | 0.6684961 |
| DES | 3635 | 1.512336 | 0.9413354 | 0.8655014 |
| LEV | 27915 | 1.043477 | 0.6898680 | 0.6641586 |

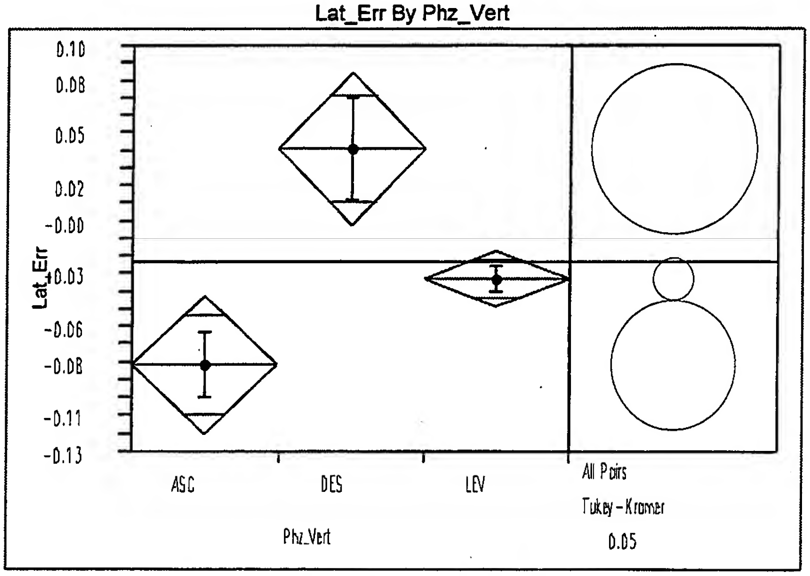
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 21.7535 | 2 | 35925 | <.0001 |
| Brown-Forsythe | 86.2379 | 2 | 35925 | <.0001 |
| Levene | 158.6746 | 2 | 35925 | <.0001 |
| Bartlett | 709.3944 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 20.3511 | 2 | 6536.1 | <.0001 |

**Figure A.1- 137 Statistical Tests for Horizontal Error and Vertical Phase of Flight at Look Ahead Time 0 for Samples at All Altitudes**

Lat_Err By Phz_Vert




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 4378 | -0.07751 | 1.27855 | 0.01932 |
| DES | 3635 | 0.042201 | 1.76059 | 0.02920 |
| LEV | 27915 | -0.02281 | 1.28779 | 0.00771 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | DES | LEV | ASC |
|---|---|---|---|
| DES | 0.000000 | 0.065006 | 0.119712 |
| LEV | -0.06501 | 0.000000 | 0.054706 |
| ASC | -0.11971 | -0.05471 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34380

| Abs(Dif)-LSD | DES | LEV | ASC |
|---|---|---|---|
| DES | -0.07379 | 0.009539 | 0.049126 |
| LEV | 0.009539 | -0.02663 | 0.003572 |
| ASC | 0.049126 | 0.003572 | -0.06723 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

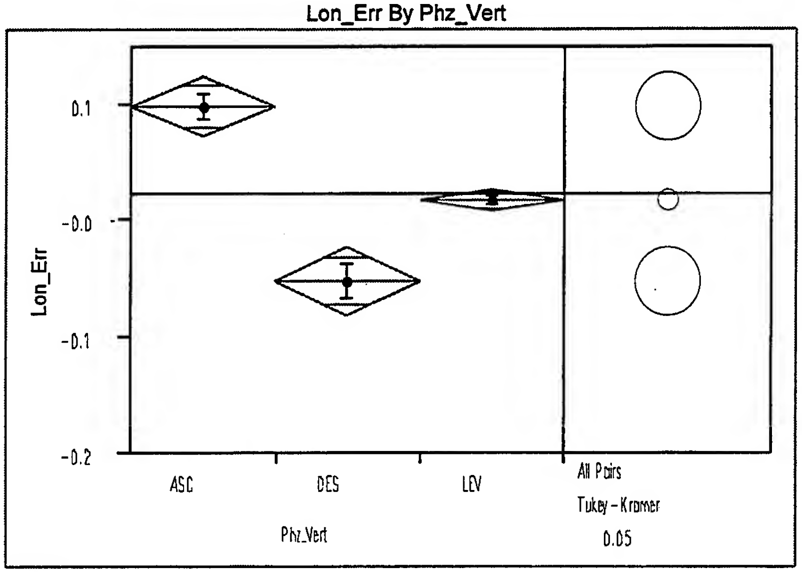
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 4378 | 1.278546 | 0.931243 | 0.930869 |
| DES | 3635 | 1.760591 | 1.017777 | 1.016730 |
| LEV | 27915 | 1.287788 | 0.842900 | 0.842389 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 51.1363 | 2 | 35925 | <.0001 |
| Brown-Forsythe | 55.6273 | 2 | 35925 | <.0001 |
| Levene | 55.9512 | 2 | 35925 | <.0001 |
| Bartlett | 379.7888 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 6.3653 | 2 | 6360.8 | 0.0017 |

**Figure A.1- 138 Statistical Tests for Lateral Error and Vertical Phase of Flight at Look Ahead Time 0 for Samples at All Altitudes**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 4378 | 0.067060 | 0.770570 | 0.01165 |
| DES | 3635 | -0.08469 | 0.999504 | 0.01658 |
| LEV | 27915 | -0.02002 | 0.913888 | 0.00547 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | ASC | LEV | DES |
|---|---|---|---|
| ASC | 0.000000 | 0.087080 | 0.151751 |
| LEV | -0.08708 | 0.000000 | 0.064671 |
| DES | -0.15175 | -0.06467 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34380

| Abs(Dif)-LSD | ASC | LEV | DES |
|---|---|---|---|
| ASC | -0.04543 | 0.052530 | 0.104058 |
| LEV | 0.052530 | -0.01799 | 0.027193 |
| DES | 0.104058 | 0.027193 | -0.04986 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

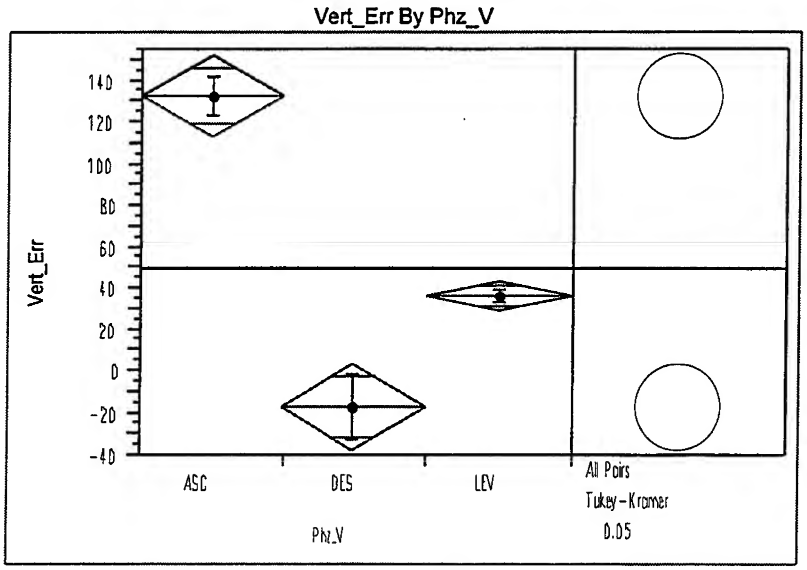
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 4378 | 0.7705700 | 0.5427742 | 0.5422585 |
| DES | 3635 | 0.9995036 | 0.6452671 | 0.6443120 |
| LEV | 27915 | 0.9138881 | 0.6131749 | 0.6131590 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 4.6313 | 2 | 35925 | 0.0097 |
| Brown-Forsythe | 27.0145 | 2 | 35925 | <.0001 |
| Levene | 27.0044 | 2 | 35925 | <.0001 |
| Bartlett | 142.8342 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 33.6990 | 2 | 6783.8 | <.0001 |

**Figure A.1- 139 Statistical Tests for Longitudinal Error and Vertical Phase of Flight at Look Ahead Time 0 for Samples at All Altitudes**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 4378 | 143.422 | 640.230 | 9.676 |
| DES | 3635 | -15.436 | 944.248 | 15.662 |
| LEV | 27915 | 43.041 | 619.130 | 3.706 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | ASC | LEV | DES |
|---|---|---|---|
| ASC | 0.000 | 100.381 | 158.857 |
| LEV | -100.381 | 0.000 | 58.476 |
| DES | -158.857 | -58.476 | 0.000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34380

| Abs(Dif)-LSD | ASC | LEV | DES |
|---|---|---|---|
| ASC | -33.153 | 75.167 | 124.051 |
| LEV | 75.167 | -13.129 | 31.125 |
| DES | 124.051 | 31.125 | -36.384 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 4378 | 640.2296 | 430.7715 | 428.1537 |
| DES | 3635 | 944.2478 | 567.4349 | 566.3651 |
| LEV | 27915 | 619.1305 | 147.9035 | 120.3874 |

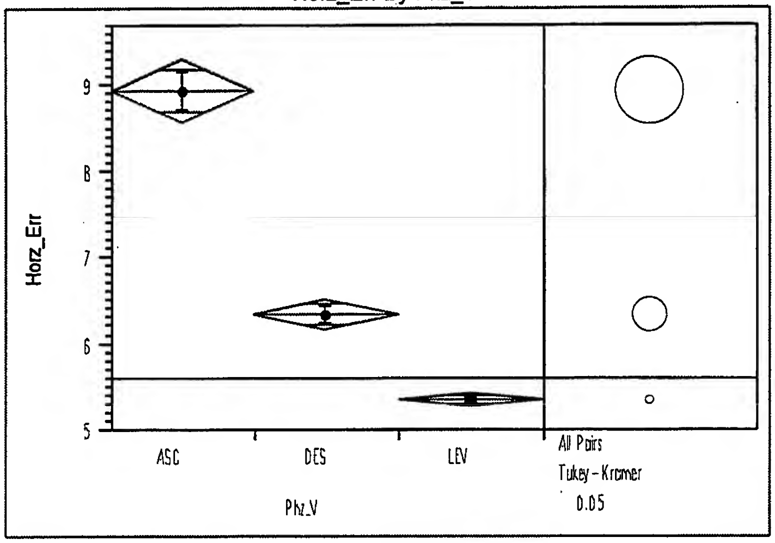
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 3.6011 | 2 | 35925 | 0.0273 |
| Brown-Forsythe | 1193.4789 | 2 | 35925 | 0.0000 |
| Levene | 1062.8404 | 2 | 35925 | 0.0000 |
| Bartlett | 713.5924 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 56.8077 | 2 | 6240.5 | <.0001 |

**Figure A.1- 140 Statistical Tests for Vertical Error and Vertical Phase of Flight at Look Ahead Time 0 for Samples at All Altitudes**

Horz_Err By Phz_V




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 818 | 8.44954 | 6.42419 | 0.22462 |
| DES | 3082 | 5.81711 | 5.62843 | 0.10138 |
| LEV | 20064 | 4.86284 | 5.34377 | 0.03773 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | ASC | DES | LEV |
|---|---|---|---|
| ASC | 0.00000 | 2.63244 | 3.58670 |
| DES | -2.63244 | 0.00000 | 0.95427 |
| LEV | -3.58670 | -0.95427 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34385

| Abs(Dif)-LSD | ASC | DES | LEV |
|---|---|---|---|
| ASC | -0.62831 | 2.13266 | 3.13345 |
| DES | 2.13266 | -0.32369 | 0.70843 |
| LEV | 3.13345 | 0.70843 | -0.12687 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 818 | 6.424191 | 5.046806 | 4.877465 |
| DES | 3082 | 5.628426 | 3.789303 | 3.578561 |
| LEV | 20064 | 5.343766 | 3.517124 | 3.210825 |

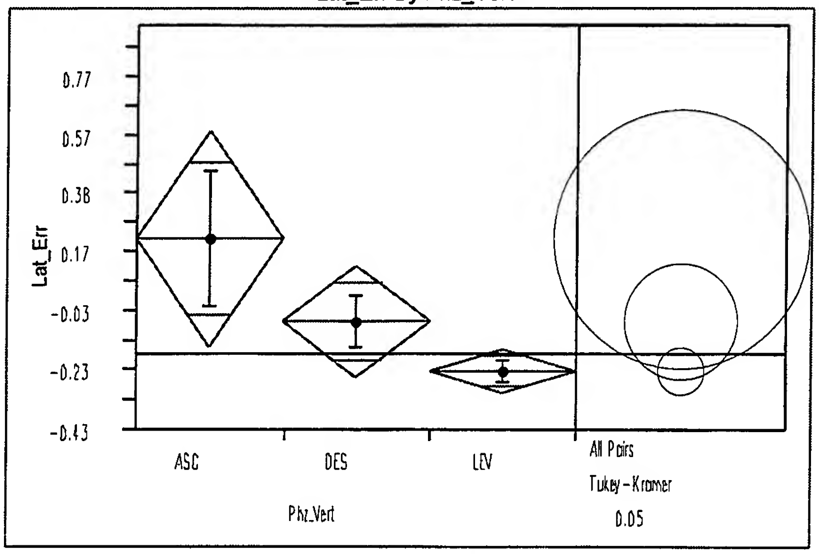
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 2.0840 | 2 | 23961 | 0.1245 |
| Brown-Forsythe | 57.8195 | 2 | 23961 | <.0001 |
| Levene | 60.0652 | 2 | 23961 | <.0001 |
| Bartlett | 34.9995 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 155.3402 | 2 | 1879.7 | <.0001 |

**Figure A.1- 141 Statistical Tests for Horizontal Error and Vertical Phase of Flight at Look Ahead Time 600 for Samples at All Altitudes**

Lat_Err By Phz_Vert




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 818 | 0.248885 | 6.75532 | 0.23619 |
| DES | 3082 | -0.03138 | 5.18980 | 0.09348 |
| LEV | 20064 | -0.20943 | 5.40798 | 0.03818 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | ASC | DES | LEV |
|---|---|---|---|
| ASC | 0.000000 | 0.280265 | 0.458314 |
| DES | -0.28027 | 0.000000 | 0.178049 |
| LEV | -0.45831 | -0.17805 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34385

| Abs(Dif)-LSD | ASC | DES | LEV |
|---|---|---|---|
| ASC | -0.62956 | -0.2205 | 0.004166 |
| DES | -0.2205 | -0.32434 | -0.06828 |
| LEV | 0.004166 | -0.06828 | -0.12712 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

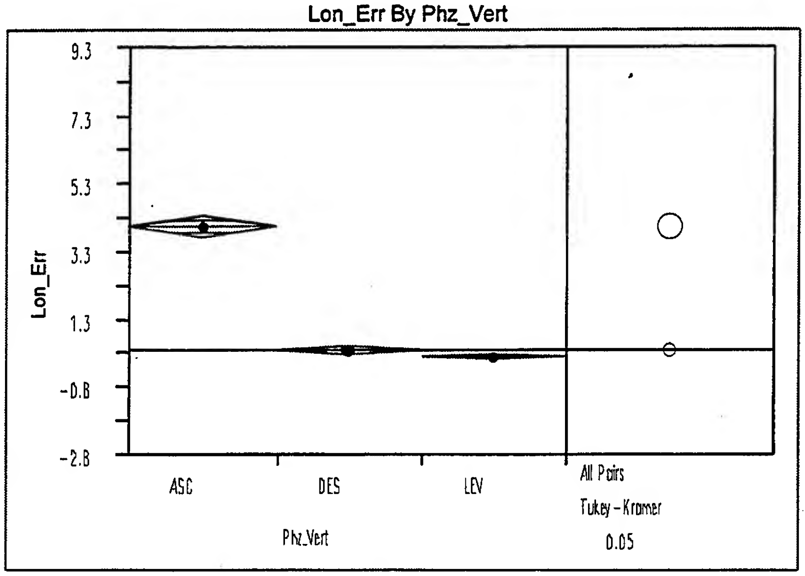
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 818 | 6.755321 | 4.029199 | 4.016305 |
| DES | 3082 | 5.189798 | 2.973750 | 2.972403 |
| LEV | 20064 | 5.407984 | 2.824707 | 2.800483 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 6.3448 | 2 | 23961 | 0.0018 |
| Brown-Forsythe | 28.2611 | 2 | 23961 | <.0001 |
| Levene | 27.6353 | 2 | 23961 | <.0001 |
| Bartlett | 51.7520 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 3.1959 | 2 | 1888 | 0.0412 |

**Figure A.1- 142 Statistical Tests for Lateral Error and Vertical Phase of Flight at Look Ahead Time 600 for Samples at All Altitudes**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 818 | 4.10383 | 7.08477 | 0.24771 |
| DES | 3082 | 0.45041 | 6.19604 | 0.11161 |
| LEV | 20064 | 0.19525 | 4.78288 | 0.03377 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | ASC | DES | LEV |
|---|---|---|---|
| ASC | 0.00000 | 3.65342 | 3.90858 |
| DES | -3.65342 | 0.00000 | 0.25516 |
| LEV | -3.90858 | -0.25516 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34385

| Abs(Dif)-LSD | ASC | DES | LEV |
|---|---|---|---|
| ASC | -0.58871 | 3.18515 | 3.48390 |
| DES | 3.18515 | -0.30329 | 0.02482 |
| LEV | 3.48390 | 0.02482 | -0.11887 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 818 | 7.084766 | 5.387357 | 5.355981 |
| DES | 3082 | 6.196044 | 4.048005 | 4.047764 |
| LEV | 20064 | 4.782883 | 3.069458 | 3.069352 |

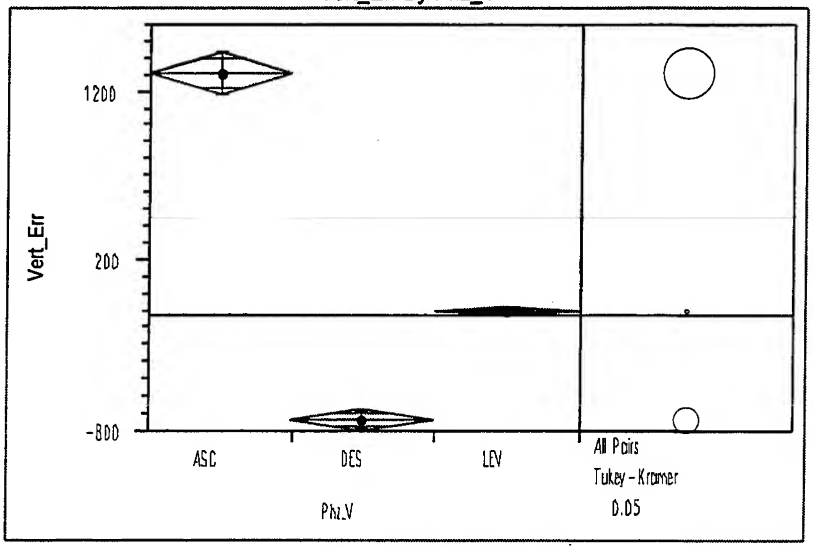
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 30.1699 | 2 | 23961 | <.0001 |
| Brown-Forsythe | 209.9188 | 2 | 23961 | <.0001 |
| Levene | 213.9512 | 2 | 23961 | <.0001 |
| Bartlett | 323.5669 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 123.4125 | 2 | 1830.1 | <.0001 |

**Figure A.1- 143 Statistical Tests for Longitudinal Error and Vertical Phase of Flight at Look Ahead Time 600 for Samples at All Altitudes**

Vert_Err By Phz_V




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 818 | 1322.70 | 3799.44 | 132.84 |
| DES | 3082 | -726.17 | 3080.04 | 55.48 |
| LEV | 20064 | -93.56 | 1551.14 | 10.95 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | ASC | LEV | DES |
|---|---|---|---|
| ASC | 0.00 | 1416.26 | 2048.87 |
| LEV | -1416.26 | 0.00 | 632.61 |
| DES | -2048.87 | -632.61 | 0.00 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34385

| Abs(Dif)-LSD | ASC | LEV | DES |
|---|---|---|---|
| ASC | -223.73 | 1254.87 | 1870.91 |
| LEV | 1254.87 | -45.17 | 545.07 |
| DES | 1870.91 | 545.07 | -115.26 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

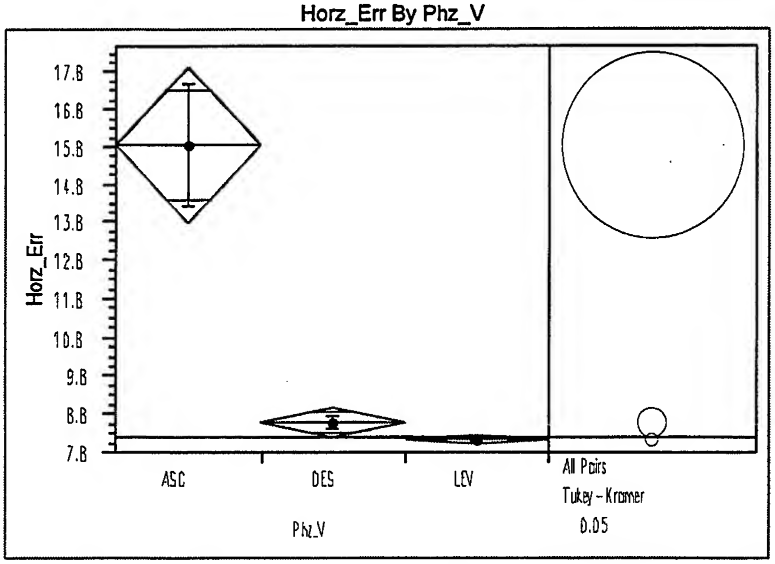
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 818 | 3799.441 | 2867.027 | 2854.848 |
| DES | 3082 | 3080.038 | 2267.361 | 2267.097 |
| LEV | 20064 | 1551.141 | 666.359 | 610.266 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 615.3838 | 2 | 23961 | <.0001 |
| Brown-Forsythe | 2125.5093 | 2 | 23961 | 0.0000 |
| Levene | 2065.6608 | 2 | 23961 | 0.0000 |
| Bartlett | 2395.9045 | 2 | ? | 0.0000 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 120.8911 | 2 | 1767.1 | <.0001 |

**Figure A.1- 144 Statistical Tests for Vertical Error and Vertical Phase of Flight at Look Ahead Time 600 for Samples at All Altitudes**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 67 | 15.8809 | 13.4629 | 1.6448 |
| DES | 1891 | 8.6502 | 7.8128 | 0.1797 |
| LEV | 11878 | 8.1401 | 8.9953 | 0.0825 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | ASC | DES | LEV |
|---|---|---|---|
| ASC | 0.00000 | 7.23073 | 7.74086 |
| DES | -7.23073 | 0.00000 | 0.51013 |
| LEV | -7.74086 | -0.51013 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34395

| Abs(Dif)-LSD | ASC | DES | LEV |
|---|---|---|---|
| ASC | -3.59216 | 4.64608 | 5.19366 |
| DES | 4.64608 | -0.67616 | -0.00464 |
| LEV | 5.19366 | -0.00464 | -0.26979 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 67 | 13.46293 | 10.10981 | 9.784099 |
| DES | 1891 | 7.81284 | 5.60207 | 5.337903 |
| LEV | 11878 | 8.99532 | 5.80692 | 5.348561 |

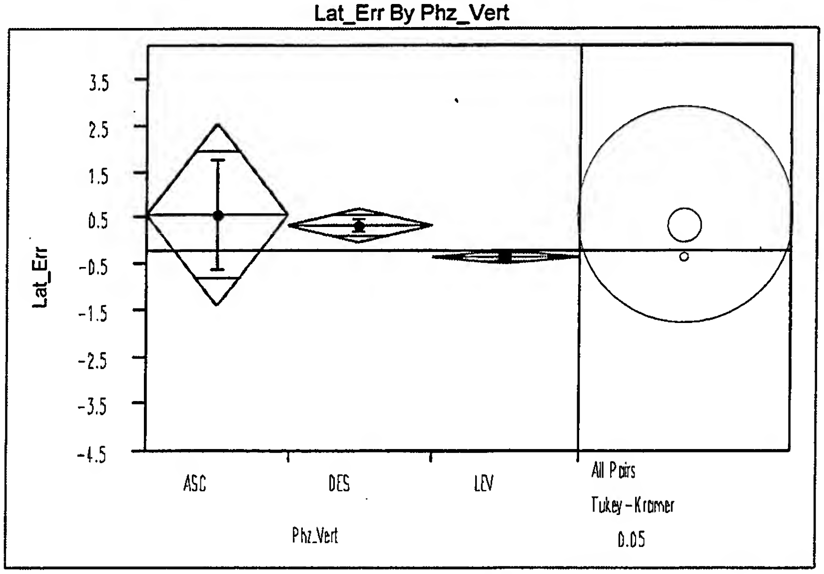
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 2.6157 | 2 | 13833 | 0.0732 |
| Brown-Forsythe | 11.6325 | 2 | 13833 | <.0001 |
| Levene | 14.6769 | 2 | 13833 | <.0001 |
| Bartlett | 45.7431 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 14.0737 | 2 | 172.57 | <.0001 |

**Figure A.1- 145 Statistical Tests for Horizontal Error and Vertical Phase of Flight at Look Ahead Time 1200 for Samples at All Altitudes**

Lat_Err By Phz_Vert




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 67 | 0.623984 | 9.90257 | 1.2098 |
| DES | 1891 | 0.412936 | 6.98297 | 0.1606 |
| LEV | 11878 | -0.31722 | 8.59878 | 0.0789 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | ASC | DES | LEV |
|---|---|---|---|
| ASC | 0.000000 | 0.211047 | 0.941200 |
| DES | -0.21105 | 0.000000 | 0.730153 |
| LEV | -0.9412 | -0.73015 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34395

| Abs(Dif)-LSD | ASC | DES | LEV |
|---|---|---|---|
| ASC | -3.40308 | -2.23756 | -1.47192 |
| DES | -2.23756 | -0.64057 | 0.24248 |
| LEV | -1.47192 | 0.24248 | -0.25559 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

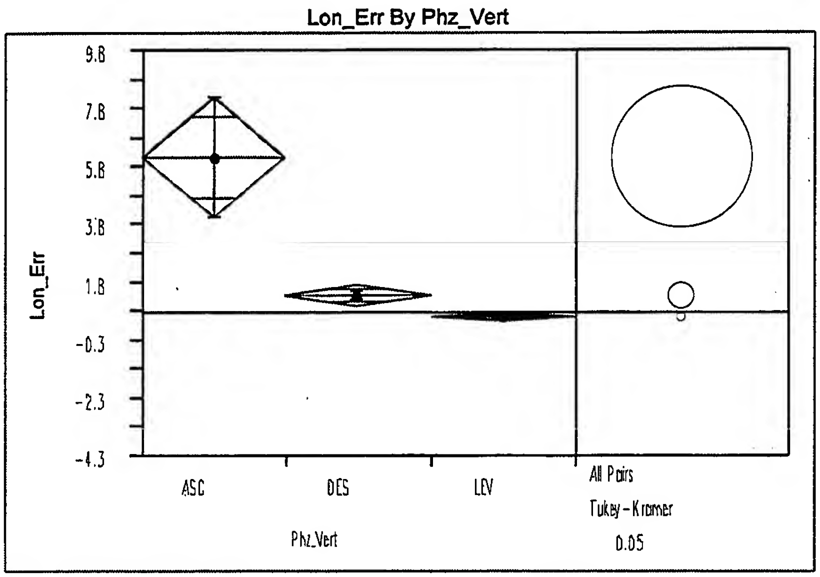
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 67 | 9.902573 | 5.255892 | 5.193390 |
| DES | 1891 | 6.982971 | 3.893166 | 3.845981 |
| LEV | 11878 | 8.598785 | 4.252223 | 4.200651 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 3.3091 | 2 | 13833 | 0.0366 |
| Brown-Forsythe | 2.5977 | 2 | 13833 | 0.0745 |
| Levene | 2.6874 | 2 | 13833 | 0.0681 |
| Bartlett | 65.6788 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 8.5118 | 2 | 173.21 | 0.0003 |

**Figure A.1- 146 Statistical Tests for Lateral Error and Vertical Phase of Flight at Look Ahead Time 1200 for Samples at All Altitudes**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 67 | 6.08724 | 17.3552 | 2.1203 |
| DES | 1891 | 1.32916 | 9.2307 | 0.2123 |
| LEV | 11878 | 0.56313 | 8.5338 | 0.0783 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | ASC | DES | LEV |
|---|---|---|---|
| ASC | 0.00000 | 4.75808 | 5.52411 |
| DES | -4.75808 | 0.00000 | 0.76602 |
| LEV | -5.52411 | -0.76602 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34395

| Abs(Dif)-LSD | ASC | DES | LEV |
|---|---|---|---|
| ASC | -3.52132 | 2.22441 | 3.02715 |
| DES | 2.22441 | -0.66282 | 0.26141 |
| LEV | 3.02715 | 0.26141 | -0.26447 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 67 | 17.35519 | 12.34545 | 12.34024 |
| DES | 1891 | 9.23068 | 6.38181 | 6.37956 |
| LEV | 11878 | 8.53376 | 5.53675 | 5.53671 |

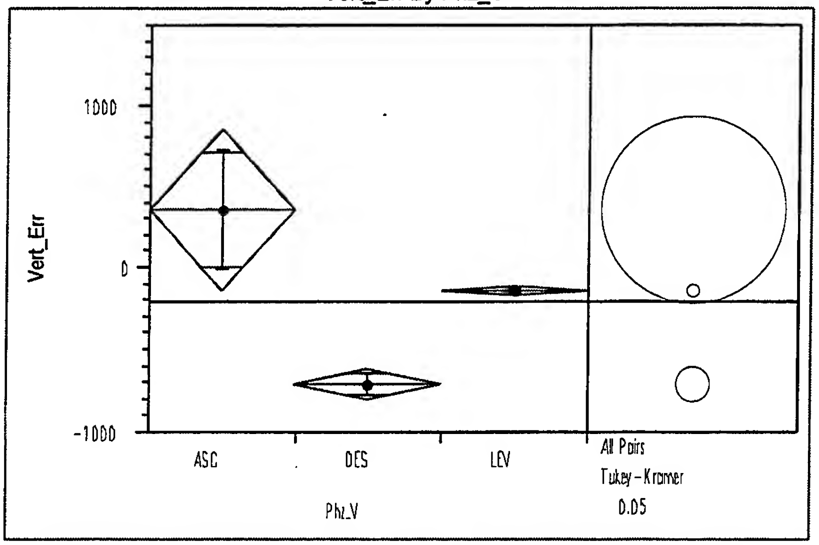
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 18.0889 | 2 | 13833 | <.0001 |
| Brown-Forsythe | 48.1627 | 2 | 13833 | <.0001 |
| Levene | 48.2980 | 2 | 13833 | <.0001 |
| Bartlett | 63.8325 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 8.9750 | 2 | 171.75 | 0.0002 |

**Figure A.1- 147 Statistical Tests for Longitudinal Error and Vertical Phase of Flight at Look Ahead Time 1200 for Samples at All Altitudes**

Vert_Err By Phz_V




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 67 | 366.593 | 3022.95 | 369.31 |
| DES | 1891 | -692.948 | 3212.21 | 73.87 |
| LEV | 11878 | -125.540 | 1861.58 | 17.08 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | ASC | LEV | DES |
|---|---|---|---|
| ASC | 0.00 | 492.13 | 1059.54 |
| LEV | -492.13 | 0.00 | 567.41 |
| DES | -1059.54 | -567.41 | 0.00 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34395

| Abs(Dif)-LSD | ASC | LEV | DES |
|---|---|---|---|
| ASC | -852.259 | -112.202 | 446.319 |
| LEV | -112.202 | -64.008 | 445.276 |
| DES | 446.319 | 445.276 | -160.422 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 67 | 3022.946 | 1936.165 | 1904.832 |
| DES | 1891 | 3212.207 | 2391.171 | 2390.027 |
| LEV | 11878 | 1861.579 | 819.093 | 744.353 |

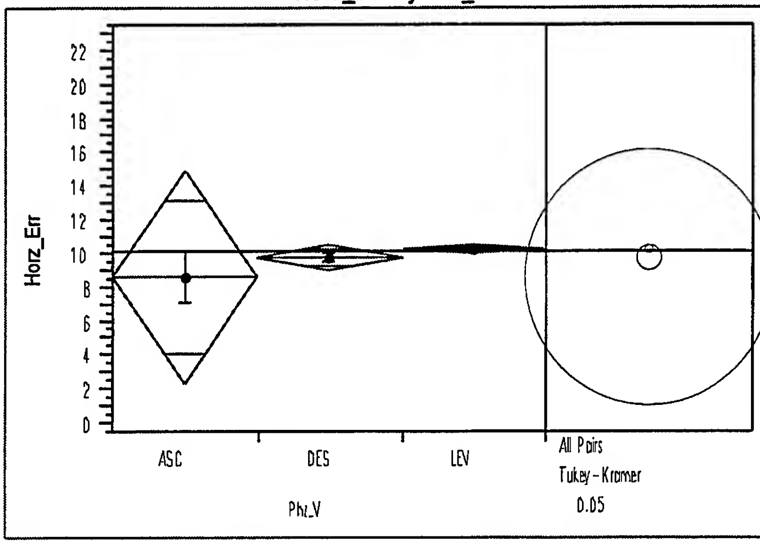
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 63.3912 | 2 | 13833 | <.0001 |
| Brown-Forsythe | 705.9509 | 2 | 13833 | <.0001 |
| Levene | 669.1486 | 2 | 13833 | <.0001 |
| Bartlett | 631.8215 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 28.8846 | 2 | 171.3 | <.0001 |

**Figure A.1- 148 Statistical Tests for Vertical Error and Vertical Phase of Flight at Look Ahead Time 1200 for Samples at All Altitudes**

Horz_Err By Phz_V




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 11 | 8.5964 | 5.0654 | 1.5273 |
| DES | 781 | 9.7114 | 9.3400 | 0.3342 |
| LEV | 5652 | 10.2329 | 11.1039 | 0.1477 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | LEV | DES | ASC |
|---|---|---|---|
| LEV | 0.00000 | 0.52155 | 1.63647 |
| DES | -0.52155 | 0.00000 | 1.11492 |
| ASC | -1.63647 | -1.11492 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34424

| Abs(Dif)-LSD | LEV | DES | ASC |
|---|---|---|---|
| LEV | -0.4806 | -0.4538 | -6.0743 |
| DES | -0.4538 | -1.2929 | -6.6424 |
| ASC | -6.0743 | -6.6424 | -10.8941 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 11 | 5.06535 | 3.624998 | 3.007345 |
| DES | 781 | 9.34000 | 6.418944 | 5.989695 |
| LEV | 5652 | 11.10395 | 7.102620 | 6.565134 |

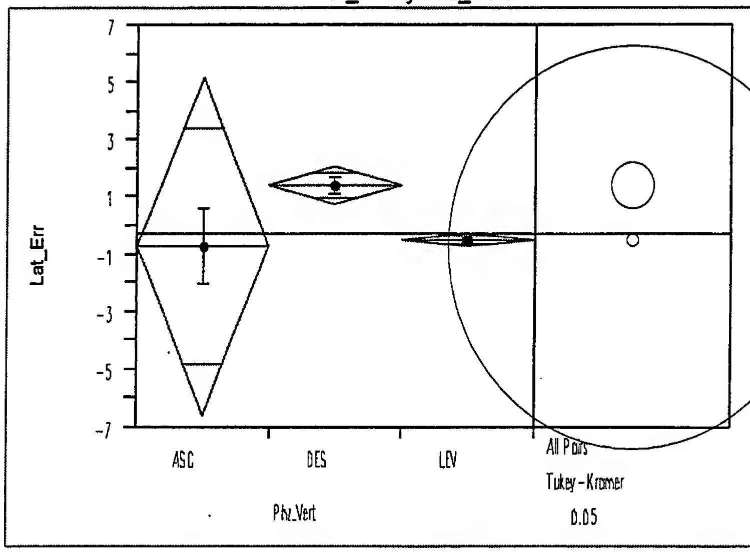
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 1.2850 | 2 | 6441 | 0.2767 |
| Brown-Forsythe | 2.0928 | 2 | 6441 | 0.1234 |
| Levene | 3.2181 | 2 | 6441 | 0.0401 |
| Bartlett | 22.1665 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 1.4934 | 2 | 26.839 | 0.2427 |

**Figure A.1- 149 Statistical Tests for Horizontal Error and Vertical Phase of Flight at Look Ahead Time 1800 for Samples at All Altitudes**

Lat_Err By Phz_Vert




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 11 | -0.66729 | 4.5378 | 1.3682 |
| DES | 781 | 1.43987 | 8.5302 | 0.3052 |
| LEV | 5652 | -0.45051 | 10.2374 | 0.1362 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | DES | LEV | ASC |
|---|---|---|---|
| DES | 0.00000 | 1.89037 | 2.10716 |
| LEV | -1.89037 | 0.00000 | 0.21678 |
| ASC | -2.10716 | -0.21678 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34424

| Abs(Dif)-LSD | DES | LEV | ASC |
|---|---|---|---|
| DES | -1.1910 | 0.9919 | -5.0388 |
| LEV | 0.9919 | -0.4427 | -6.8863 |
| ASC | -5.0388 | -6.8863 | -10.0355 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 11 | 4.53782 | 2.342874 | 1.988864 |
| DES | 781 | 8.53021 | 4.643592 | 4.332618 |
| LEV | 5652 | 10.23743 | 4.896145 | 4.803751 |

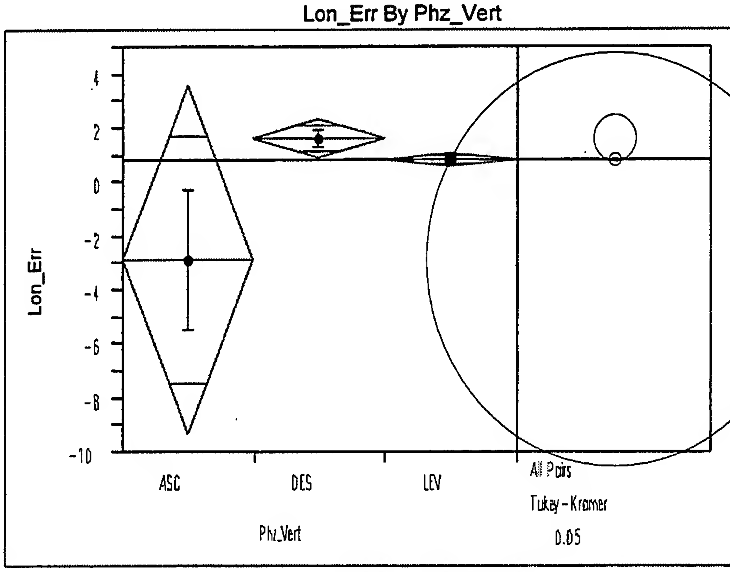
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 1.0921 | 2 | 6441 | 0.3356 |
| Brown-Forsythe | 1.4992 | 2 | 6441 | 0.2234 |
| Levene | 0.7367 | 2 | 6441 | 0.4787 |
| Bartlett | 24.3585 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 15.6798 | 2 | 26.863 | <.0001 |

**Figure A.1- 150 Statistical Tests for Lateral Error and Vertical Phase of Flight at Look Ahead Time 1800 for Samples at All Altitudes**

Lon_Err By Phz_Vert




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 11 | -2.91244 | 8.7484 | 2.6377 |
| DES | 781 | 1.57001 | 10.2156 | 0.3655 |
| LEV | 5652 | 0.78698 | 11.0635 | 0.1472 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | DES | LEV | ASC |
|---|---|---|---|
| DES | 0.00000 | 0.78303 | 4.48245 |
| LEV | -0.78303 | 0.00000 | 3.69942 |
| ASC | -4.48245 | -3.69942 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34424

| Abs(Dif)-LSD | DES | LEV | ASC |
|---|---|---|---|
| DES | -1.3003 | -0.1979 | -3.3194 |
| LEV | -0.1979 | -0.4834 | -4.0556 |
| ASC | -3.3194 | -4.0556 | -10.9566 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 11 | 8.74840 | 6.867015 | 6.879182 |
| DES | 781 | 10.21560 | 7.191399 | 7.189635 |
| LEV | 5652 | 11.06351 | 7.398194 | 7.398110 |

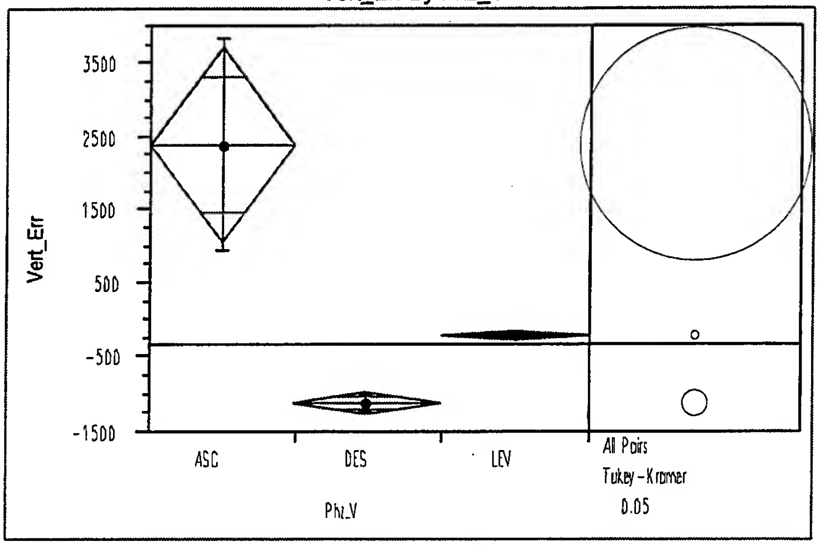
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 0.8785 | 2 | 6441 | 0.4155 |
| Brown-Forsythe | 0.2470 | 2 | 6441 | 0.7811 |
| Levene | 0.2445 | 2 | 6441 | 0.7831 |
| Bartlett | 4.5491 | 2 | ? | 0.0106 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 2.9401 | 2 | 26.555 | 0.0702 |

**Figure A.1- 151 Statistical Tests for Longitudinal Error and Vertical Phase of Flight at Look Ahead Time 1800 for Samples at All Altitudes**

Vert_Err By Phz_V




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 11 | 2367.53 | 4803.94 | 1448.4 |
| DES | 781 | -1135.50 | 3374.12 | 120.7 |
| LEV | 5652 | -220.69 | 2072.25 | 27.6 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | ASC | LEV | DES |
|---|---|---|---|
| ASC | 0.00 | 2588.22 | 3503.03 |
| LEV | -2588.22 | 0.00 | 914.81 |
| DES | -3503.03 | -914.81 | 0.00 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34424

| Abs(Dif)-LSD | ASC | LEV | DES |
|---|---|---|---|
| ASC | -2275.47 | 977.65 | 1882.74 |
| LEV | 977.65 | -100.38 | 711.09 |
| DES | 1882.74 | 711.09 | -270.05 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 11 | 4803.938 | 2701.043 | 2176.435 |
| DES | 781 | 3374.120 | 2569.823 | 2568.367 |
| LEV | 5652 | 2072.252 | 998.330 | 868.832 |

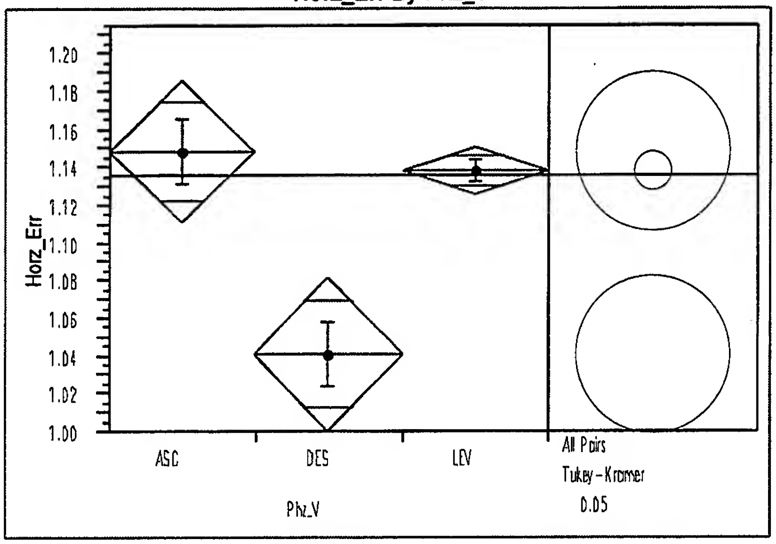
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 24.0650 | 2 | 6441 | <.0001 |
| Brown-Forsythe | 265.3004 | 2 | 6441 | <.0001 |
| Levene | 246.0753 | 2 | 6441 | <.0001 |
| Bartlett | 212.9661 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 28.2223 | 2 | 26.379 | <.0001 |

**Figure A.1- 152 Statistical Tests for Vertical Error and Vertical Phase of Flight at Look Ahead Time 1800 for Samples at All Altitudes**

Horz_Err By Phz_V




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 2345 | 1.15130 | 0.870731 | 0.01798 |
| DES | 2012 | 1.04303 | 0.784722 | 0.01749 |
| LEV | 21791 | 1.14400 | 0.962867 | 0.00652 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | ASC | LEV | DES |
|---|---|---|---|
| ASC | 0.000000 | 0.007301 | 0.108269 |
| LEV | -0.0073 | 0.000000 | 0.100967 |
| DES | -0.10827 | -0.10097 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

$q^* = 2.34383$

| Abs(Dif)-LSD | ASC | LEV | DES |
|---|---|---|---|
| ASC | -0.0645 | -0.0407 | 0.041149 |
| LEV | -0.0407 | -0.02116 | 0.049503 |
| DES | 0.041149 | 0.049503 | -0.06964 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

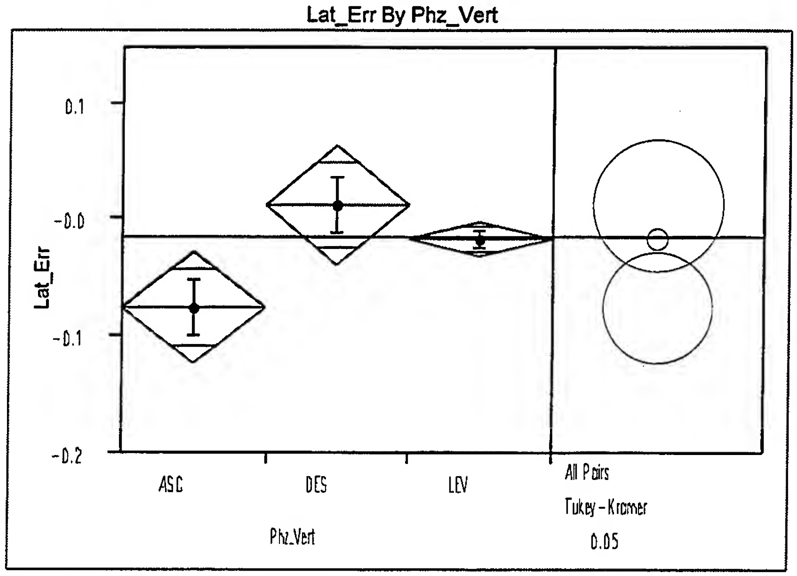
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 2345 | 0.8707308 | 0.6552957 | 0.6368770 |
| DES | 2012 | 0.7847219 | 0.6138153 | 0.5928690 |
| LEV | 21791 | 0.9628669 | 0.6538652 | 0.6327879 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 0.7900 | 2 | 26145 | 0.4539 |
| Brown-Forsythe | 2.8765 | 2 | 26145 | 0.0563 |
| Levene | 3.2358 | 2 | 26145 | 0.0393 |
| Bartlett | 84.0044 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 15.1528 | 2 | 3606.9 | <.0001 |

**Figure A.1- 153 Statistical Tests for Horizontal Error and Vertical Phase of Flight at Look Ahead Time 0 for Samples at Altitudes Above 18,000 Feet**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 2345 | -0.07831 | 1.21484 | 0.02509 |
| DES | 2012 | 0.004360 | 1.11046 | 0.02476 |
| LEV | 21791 | -0.02187 | 1.20537 | 0.00817 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | DES | LEV | ASC |
|---|---|---|---|
| DES | 0.000000 | 0.026231 | 0.082669 |
| LEV | -0.02623 | 0.000000 | 0.056437 |
| ASC | -0.08267 | -0.05644 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34383

| Abs(Dif)-LSD | DES | LEV | ASC |
|---|---|---|---|
| DES | -0.08862 | -0.03926 | -0.00274 |
| LEV | -0.03926 | -0.02693 | -0.00465 |
| ASC | -0.00274 | -0.00465 | -0.08208 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

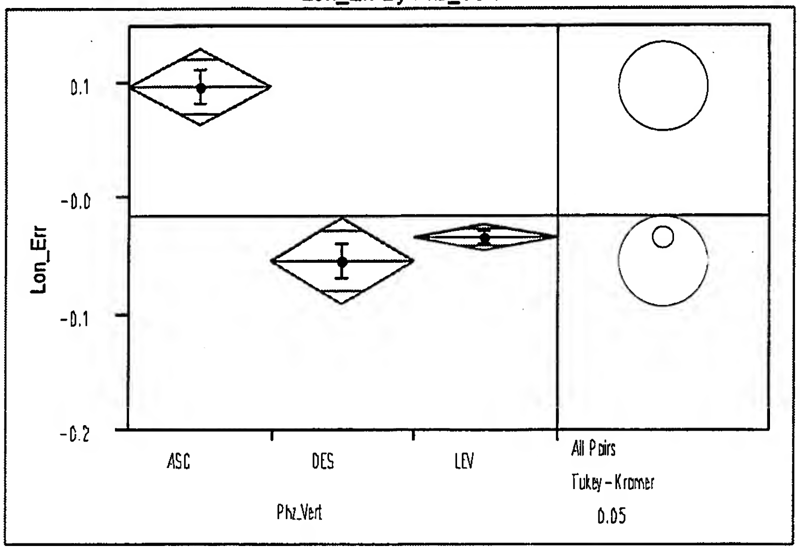
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 2345 | 1.214843 | 0.8550664 | 0.8544570 |
| DES | 2012 | 1.110456 | 0.7525471 | 0.7524417 |
| LEV | 21791 | 1.205367 | 0.8030197 | 0.8025734 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 0.8467 | 2 | 26145 | 0.4288 |
| Brown-Forsythe | 7.1615 | 2 | 26145 | 0.0008 |
| Levene | 7.2410 | 2 | 26145 | 0.0007 |
| Bartlett | 12.2711 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 3.0310 | 2 | 3467.4 | 0.0484 |

**Figure A.1- 154 Statistical Tests for Lateral Error and Vertical Phase of Flight at Look Ahead Time 0 for Samples at Altitudes Above 18,000 Feet**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 2345 | 0.090018 | 0.770811 | 0.01592 |
| DES | 2012 | -0.05311 | 0.684320 | 0.01526 |
| LEV | 21791 | -0.03422 | 0.883940 | 0.00599 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | ASC | LEV | DES |
|---|---|---|---|
| ASC | 0.000000 | 0.124241 | 0.143130 |
| LEV | -0.12424 | 0.000000 | 0.018889 |
| DES | -0.14313 | -0.01889 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34383

| Abs(Dif)-LSD | ASC | LEV | DES |
|---|---|---|---|
| ASC | -0.0589 | 0.080407 | 0.081839 |
| LEV | 0.080407 | -0.01932 | -0.02811 |
| DES | 0.081839 | -0.02811 | -0.06359 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 2345 | 0.7708108 | 0.5525002 | 0.5517916 |
| DES | 2012 | 0.6843200 | 0.5256625 | 0.5251193 |
| LEV | 21791 | 0.8839398 | 0.6007800 | 0.6007332 |

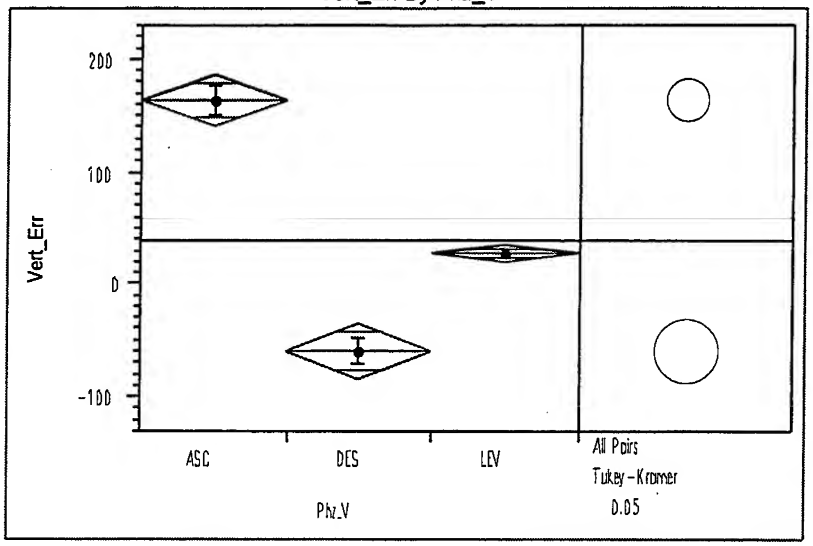
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 2.6021 | 2 | 26145 | 0.0741 |
| Brown-Forsythe | 18.3921 | 2 | 26145 | <.0001 |
| Levene | 18.0895 | 2 | 26145 | <.0001 |
| Bartlett | 133.5388 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 28.9052 | 2 | 3668.4 | <.0001 |

**Figure A.1- 155 Statistical Tests for Longitudinal Error and Vertical Phase of Flight at Look Ahead Time 0 for Samples at Altitudes Above 18,000 Feet**

Vert_Err By Phz_V




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 2345 | 164.895 | 689.815 | 14.245 |
| DES | 2012 | -54.944 | 548.348 | 12.225 |
| LEV | 21791 | 33.862 | 582.105 | 3.943 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | ASC | LEV | DES |
|---|---|---|---|
| ASC | 0.000 | 131.034 | 219.839 |
| LEV | -131.034 | 0.000 | 88.805 |
| DES | -219.839 | -88.805 | 0.000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34383

| Abs(Dif)-LSD | ASC | LEV | DES |
|---|---|---|---|
| ASC | -40.391 | 100.976 | 177.810 |
| LEV | 100.976 | -13.250 | 56.580 |
| DES | 177.810 | 56.580 | -43.605 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 2345 | 689.8154 | 427.7717 | 425.2546 |
| DES | 2012 | 548.3482 | 409.4158 | 409.4063 |
| LEV | 21791 | 582.1048 | 104.2496 | 79.2132 |

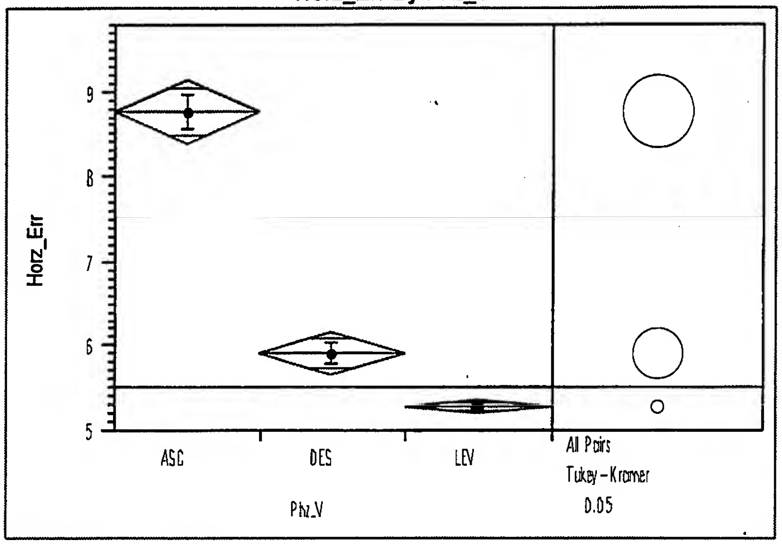
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 0.1437 | 2 | 26145 | 0.8661 |
| Brown-Forsythe | 661.5128 | 2 | 26145 | <.0001 |
| Levene | 582.1952 | 2 | 26145 | <.0001 |
| Bartlett | 77.9068 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 68.6614 | 2 | 3385.8 | <.0001 |

**Figure A.1- 156 Statistical Tests for Vertical Error and Vertical Phase of Flight at Look Ahead Time 0 for Samples at Altitudes Above 18,000 Feet**

Horz_Err By Phz_V




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 790 | 8.50273 | 6.35945 | 0.22626 |
| DES | 1599 | 5.64080 | 5.70905 | 0.14277 |
| LEV | 15821 | 5.01378 | 5.61371 | 0.04463 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | ASC | DES | LEV |
|---|---|---|---|
| ASC | 0.00000 | 2.86194 | 3.48895 |
| DES | -2.86194 | 0.00000 | 0.62701 |
| LEV | -3.48895 | -0.62701 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34389

| Abs(Dif)-LSD | ASC | DES | LEV |
|---|---|---|---|
| ASC | -0.66709 | 2.28537 | 3.00561 |
| DES | 2.28537 | -0.46889 | 0.27911 |
| LEV | 3.00561 | 0.27911 | -0.14907 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 790 | 6.359453 | 5.014433 | 4.848607 |
| DES | 1599 | 5.709050 | 3.981934 | 3.676897 |
| LEV | 15821 | 5.613709 | 3.684837 | 3.350665 |

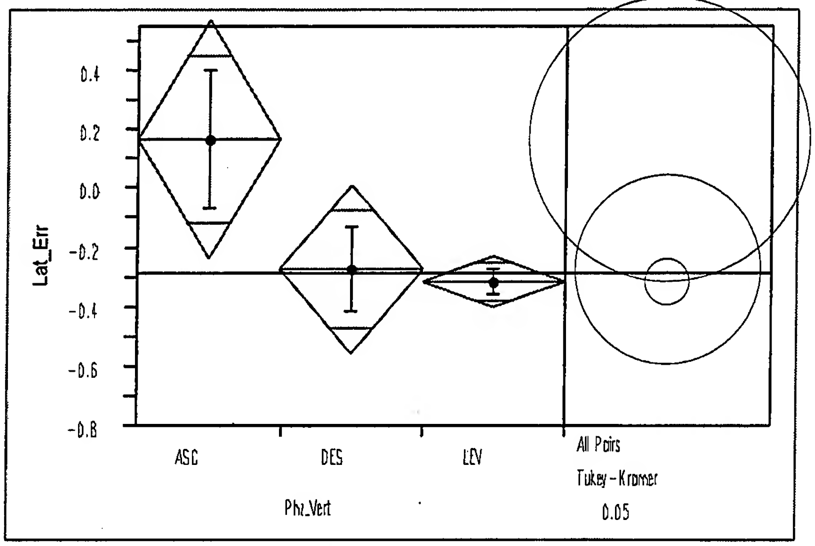
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 0.7348 | 2 | 18207 | 0.4796 |
| Brown-Forsythe | 38.5177 | 2 | 18207 | <.0001 |
| Levene | 39.7989 | 2 | 18207 | <.0001 |
| Bartlett | 12.7644 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 119.9102 | 2 | 1563.2 | <.0001 |

**Figure A.1- 157 Statistical Tests for Horizontal Error and Vertical Phase of Flight at Look Ahead Time 600 for Samples at Altitudes Above 18,000 Feet**

Lat_Err By Phz_Vert




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 790 | 0.229566 | 6.73511 | 0.23962 |
| DES | 1599 | -0.18682 | 5.73576 | 0.14344 |
| LEV | 15821 | -0.26056 | 5.77479 | 0.04591 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | ASC | DES | LEV |
|---|---|---|---|
| ASC | 0.000000 | 0.416381 | 0.490126 |
| DES | -0.41638 | 0.000000 | 0.073745 |
| LEV | -0.49013 | -0.07375 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34389

| Abs(Dif)-LSD | ASC | DES | LEV |
|---|---|---|---|
| ASC | -0.68594 | -0.17648 | -0.00687 |
| DES | -0.17648 | -0.48214 | -0.284 |
| LEV | -0.00687 | -0.284 | -0.15328 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

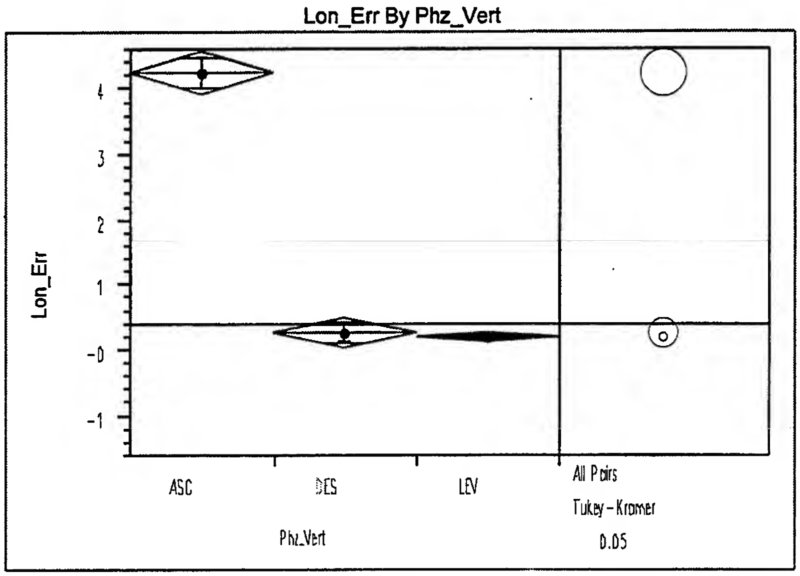
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 790 | 6.735109 | 4.017441 | 4.005424 |
| DES | 1599 | 5.735762 | 3.189536 | 3.171637 |
| LEV | 15821 | 5.774790 | 3.036701 | 2.999845 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 2.3574 | 2 | 18207 | 0.0947 |
| Brown-Forsythe | 15.9928 | 2 | 18207 | <.0001 |
| Levene | 15.2786 | 2 | 18207 | <.0001 |
| Bartlett | 19.8710 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 2.0872 | 2 | 1562.8 | 0.1244 |

**Figure A.1- 158 Statistical Tests for Lateral Error and Vertical Phase of Flight at Look Ahead Time 600 for Samples at Altitudes Above 18,000 Feet**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 790 | 4.26534 | 7.01428 | 0.24956 |
| DES | 1599 | 0.28032 | 5.60529 | 0.14018 |
| LEV | 15821 | 0.21882 | 4.81553 | 0.03828 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | ASC | DES | LEV |
|---|---|---|---|
| ASC | 0.00000 | 3.98502 | 4.04652 |
| DES | -3.98502 | 0.00000 | 0.06149 |
| LEV | -4.04652 | -0.06149 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34389

| Abs(Dif)-LSD | ASC | DES | LEV |
|---|---|---|---|
| ASC | -0.59013 | 3.47497 | 3.61894 |
| DES | 3.47497 | -0.41480 | -0.24628 |
| LEV | 3.61894 | -0.24628 | -0.13187 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

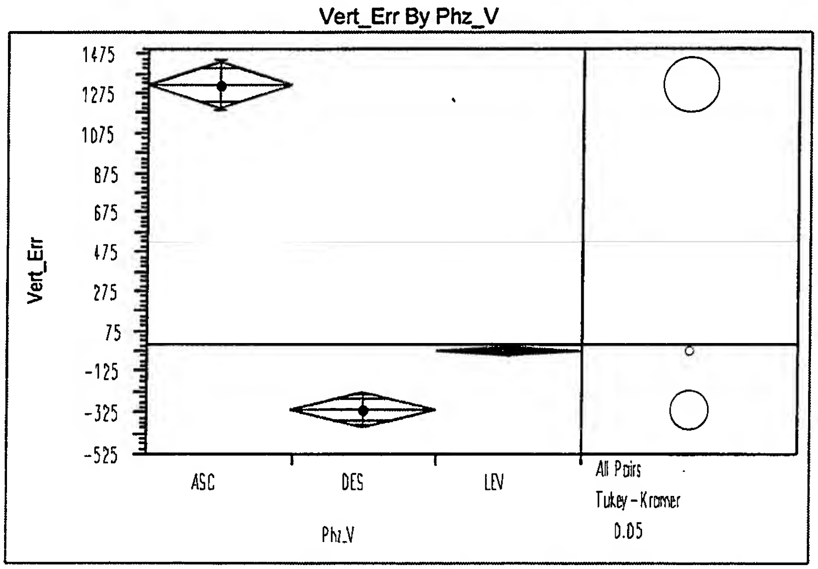
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 790 | 7.014278 | 5.380801 | 5.350096 |
| DES | 1599 | 5.605288 | 3.669638 | 3.663329 |
| LEV | 15821 | 4.815533 | 3.053748 | 3.052405 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 15.3261 | 2 | 18207 | <.0001 |
| Brown-Forsythe | 149.0593 | 2 | 18207 | <.0001 |
| Levene | 153.3746 | 2 | 18207 | <.0001 |
| Bartlett | 159.0890 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 128.4044 | 2 | 1517 | <.0001 |

**Figure A.1- 159 Statistical Tests for Longitudinal Error and Vertical Phase of Flight at Look Ahead Time 600 for Samples at Altitudes Above 18,000 Feet**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 790 | 1329.85 | 3826.34 | 136.14 |
| DES | 1599 | -307.77 | 3063.43 | 76.61 |
| LEV | 15821 | -20.23 | 1426.57 | 11.34 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | ASC | LEV | DES |
|---|---|---|---|
| ASC | 0.00 | 1350.08 | 1637.62 |
| LEV | -1350.08 | 0.00 | 287.54 |
| DES | -1637.62 | -287.54 | 0.00 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34389

| Abs(Dif)-LSD | ASC | LEV | DES |
|---|---|---|---|
| ASC | -211.84 | 1196.59 | 1454.53 |
| LEV | 1196.59 | -47.34 | 177.06 |
| DES | 1454.53 | 177.06 | -148.90 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 790 | 3826.340 | 2892.154 | 2878.453 |
| DES | 1599 | 3063.425 | 2243.293 | 2223.390 |
| LEV | 15821 | 1426.566 | 520.903 | 507.304 |

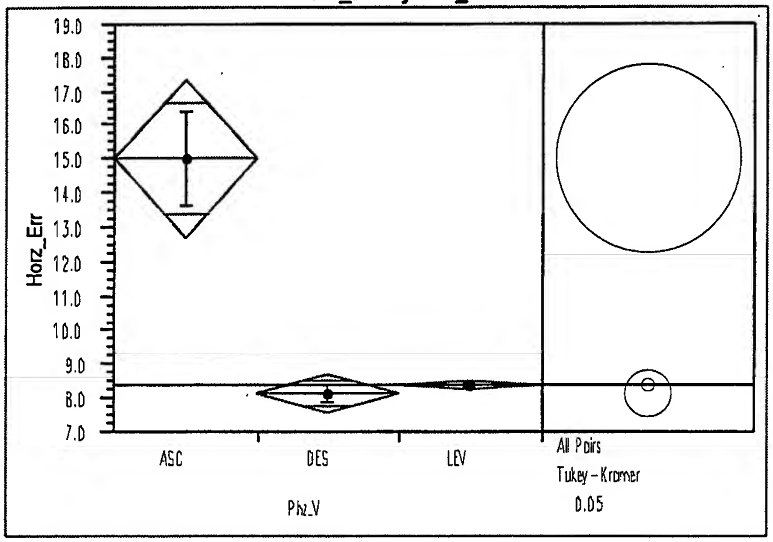
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 500.6528 | 2 | 18207 | <.0001 |
| Brown-Forsythe | 1794.4347 | 2 | 18207 | 0.0000 |
| Levene | 1832.2859 | 2 | 18207 | 0.0000 |
| Bartlett | 2194.7295 | 2 | ? | 0.0000 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 56.1576 | 2 | 1441.6 | <.0001 |

**Figure A.1- 160 Statistical Tests for Vertical Error and Vertical Phase of Flight at Look Ahead Time 600 for Samples at Altitudes Above 18,000 Feet**

Horz_Err By Phz_V




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 60 | 15.1133 | 11.1476 | 1.4391 |
| DES | 954 | 8.1625 | 8.1071 | 0.2625 |
| LEV | 9360 | 8.4334 | 9.4055 | 0.0972 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | ASC | LEV | DES |
|---|---|---|---|
| ASC | 0.00000 | 6.67988 | 6.95079 |
| LEV | -6.67988 | 0.00000 | 0.27090 |
| DES | -6.95079 | -0.27090 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34404

| Abs(Dif)-LSD | ASC | LEV | DES |
|---|---|---|---|
| ASC | -3.98207 | 3.85512 | 4.04784 |
| LEV | 3.85512 | -0.31882 | -0.47036 |
| DES | 4.04784 | -0.47036 | -0.99864 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

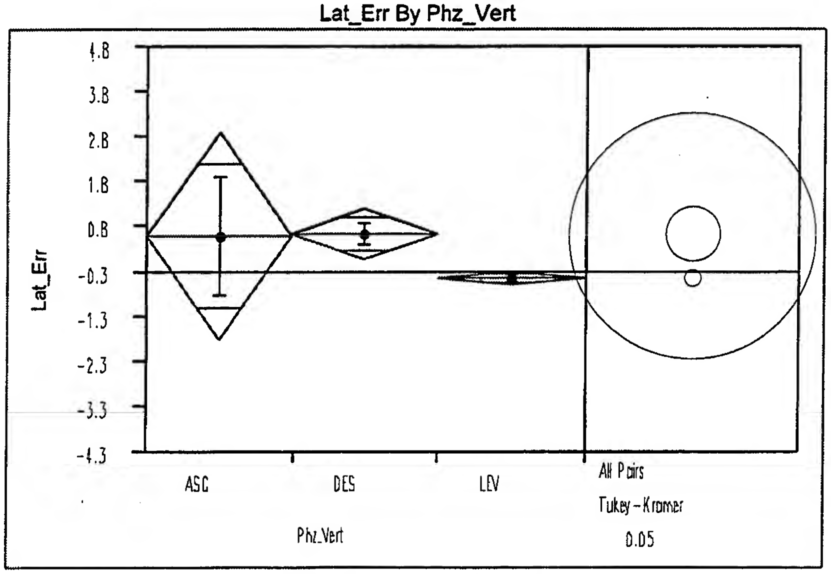
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 60 | 11.14761 | 8.926659 | 8.792062 |
| DES | 954 | 8.10711 | 5.683671 | 5.332744 |
| LEV | 9360 | 9.40554 | 6.027817 | 5.546812 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 0.8049 | 2 | 10371 | 0.4472 |
| Brown-Forsythe | 5.3426 | 2 | 10371 | 0.0048 |
| Levene | 6.1057 | 2 | 10371 | 0.0022 |
| Bartlett | 19.7546 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 11.2529 | 2 | 151.28 | <.0001 |

**Figure A.1- 161 Statistical Tests for Horizontal Error and Vertical Phase of Flight at Look Ahead Time 1200 for Samples at Altitudes Above 18,000 Feet**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 60 | 0.544405 | 10.3652 | 1.3381 |
| DES | 954 | 0.639600 | 7.8553 | 0.2543 |
| LEV | 9360 | -0.36263 | 9.2916 | 0.0960 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | DES | ASC | LEV |
|---|---|---|---|
| DES | 0.00000 | 0.09520 | 1.00223 |
| ASC | -0.09520 | 0.00000 | 0.90704 |
| LEV | -1.00223 | -0.90704 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34404

| Abs(Dif)-LSD | DES | ASC | LEV |
|---|---|---|---|
| DES | -0.98478 | -2.76745 | 0.27126 |
| ASC | -2.76745 | -3.92679 | -1.87851 |
| LEV | 0.27126 | -1.87851 | -0.31439 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

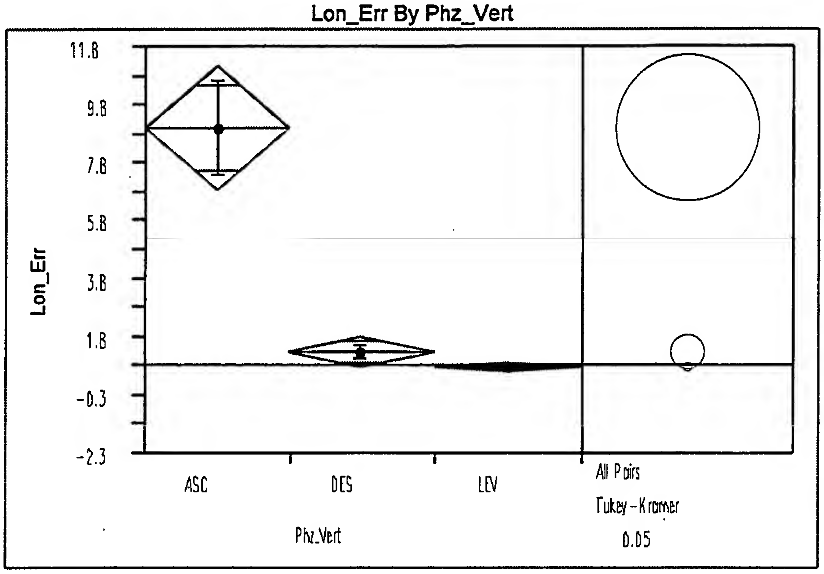
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 60 | 10.36523 | 5.448780 | 5.400325 |
| DES | 954 | 7.85527 | 4.379056 | 4.274972 |
| LEV | 9360 | 9.29163 | 4.686891 | 4.621213 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 1.3199 | 2 | 10371 | 0.2672 |
| Brown-Forsythe | 1.1313 | 2 | 10371 | 0.3226 |
| Levene | 0.9555 | 2 | 10371 | 0.3846 |
| Bartlett | 23.1685 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 6.9352 | 2 | 151.48 | 0.0013 |

**Figure A.1- 162 Statistical Tests for Lateral Error and Vertical Phase of Flight at Look Ahead Time 1200 for Samples at Altitudes Above 18,000 Feet**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 60 | 8.98926 | 12.9088 | 1.6665 |
| DES | 954 | 1.25311 | 8.2907 | 0.2684 |
| LEV | 9360 | 0.69940 | 8.5229 | 0.0881 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | ASC | DES | LEV |
|---|---|---|---|
| ASC | 0.00000 | 7.73615 | 8.28985 |
| DES | -7.73615 | 0.00000 | 0.55371 |
| LEV | -8.28985 | -0.55371 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34404

| Abs(Dif)-LSD | ASC | DES | LEV |
|---|---|---|---|
| ASC | -3.65187 | 5.07392 | 5.69933 |
| DES | 5.07392 | -0.91583 | -0.12609 |
| LEV | 5.69933 | -0.12609 | -0.29238 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

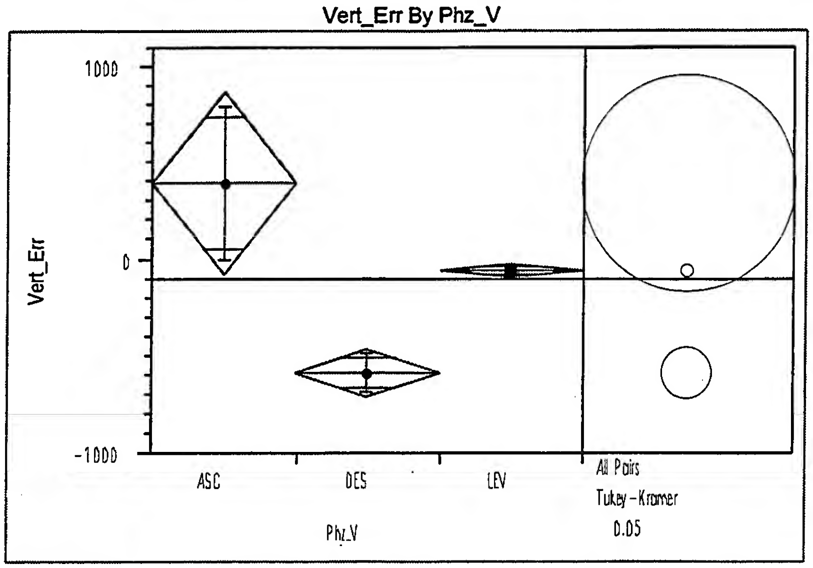
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 60 | 12.90878 | 10.76249 | 10.68907 |
| DES | 954 | 8.29067 | 5.49484 | 5.49171 |
| LEV | 9360 | 8.52287 | 5.51051 | 5.50763 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 2.3405 | 2 | 10371 | 0.0963 |
| Brown-Forsythe | 19.0557 | 2 | 10371 | <.0001 |
| Levene | 19.6194 | 2 | 10371 | <.0001 |
| Bartlett | 14.3354 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 14.0398 | 2 | 150.48 | <.0001 |

**Figure A.1- 163 Statistical Tests for Longitudinal Error and Vertical Phase of Flight at Look Ahead Time 1200 for Samples at Altitudes Above 18,000 Feet**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 60 | 393.245 | 3155.29 | 407.35 |
| DES | 954 | -580.416 | 3150.19 | 101.99 |
| LEV | 9360 | -57.599 | 1735.54 | 17.94 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | ASC | LEV | DES |
|---|---|---|---|
| ASC | 0.000 | 450.844 | 973.661 |
| LEV | -450.844 | 0.000 | 522.817 |
| DES | -973.661 | -522.817 | 0.000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34404

| Abs(Dif)-LSD | ASC | LEV | DES |
|---|---|---|---|
| ASC | -821.719 | -132.059 | 374.624 |
| LEV | -132.059 | -65.790 | 369.854 |
| DES | 374.624 | 369.854 | -206.075 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 60 | 3155.288 | 2032.020 | 1986.479 |
| DES | 954 | 3150.193 | 2296.068 | 2290.300 |
| LEV | 9360 | 1735.538 | 640.975 | 603.384 |

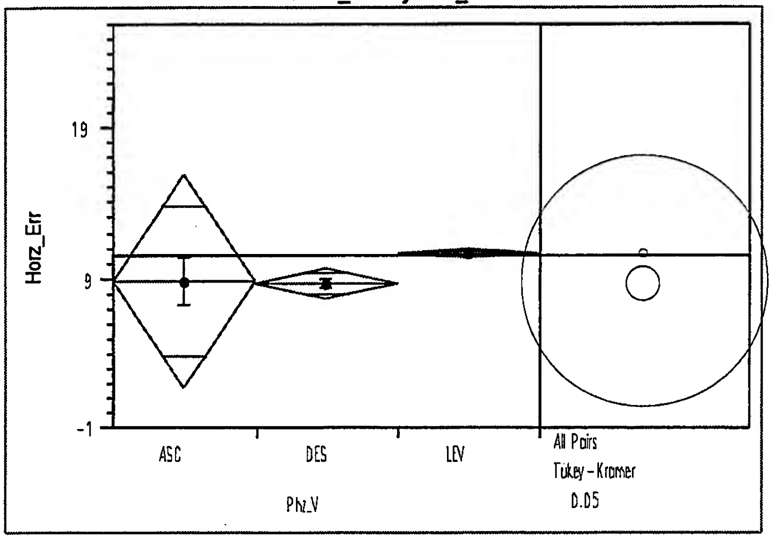
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 29.8949 | 2 | 10371 | <.0001 |
| Brown-Forsythe | 446.4619 | 2 | 10371 | <.0001 |
| Levene | 438.7175 | 2 | 10371 | <.0001 |
| Bartlett | 443.2608 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 13.3392 | 2 | 149.2 | <.0001 |

**Figure A.1- 164 Statistical Tests for Vertical Error and Vertical Phase of Flight at Look Ahead Time 1200 for Samples at Altitudes Above 18,000 Feet**

Horz_Err By Phz_V




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 10 | 8.8798 | 5.2467 | 1.6591 |
| DES | 435 | 8.6888 | 8.4504 | 0.4052 |
| LEV | 4446 | 10.8108 | 11.8025 | 0.1770 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | LEV | ASC | DES |
|---|---|---|---|
| LEV | 0.00000 | 1.93105 | 2.12201 |
| ASC | -1.93105 | 0.00000 | 0.19096 |
| DES | -2.12201 | -0.19096 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34442

| Abs(Dif)-LSD | LEV | ASC | DES |
|---|---|---|---|
| LEV | -0.5736 | -6.6305 | 0.7634 |
| ASC | -6.6305 | -12.0943 | -8.4588 |
| DES | 0.7634 | -8.4588 | -1.8337 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

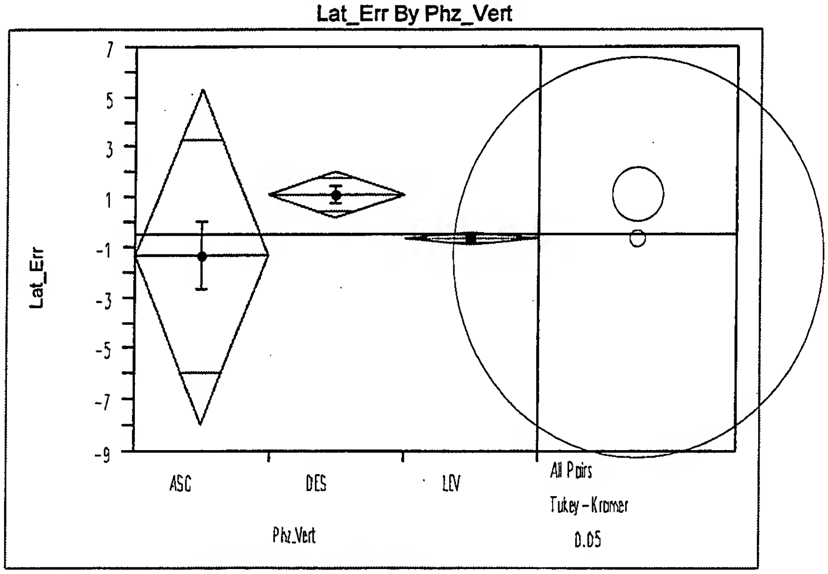
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 10 | 5.24666 | 3.817498 | 3.166610 |
| DES | 435 | 8.45044 | 5.712232 | 5.272187 |
| LEV | 4446 | 11.80248 | 7.524539 | 6.968179 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 2.0195 | 2 | 4888 | 0.1328 |
| Brown-Forsythe | 6.5529 | 2 | 4888 | 0.0014 |
| Levene | 9.0729 | 2 | 4888 | 0.0001 |
| Bartlett | 39.6519 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 11.6500 | 2 | 24.099 | 0.0003 |

**Figure A.1- 165 Statistical Tests for Horizontal Error and Vertical Phase of Flight at Look Ahead Time 1800 for Samples at Altitudes Above 18,000 Feet**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 10 | -1.23892 | 4.3458 | 1.3743 |
| DES | 435 | 1.16046 | 7.5323 | 0.3611 |
| LEV | 4446 | -0.59905 | 11.0126 | 0.1652 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | DES | LEV | ASC |
|---|---|---|---|
| DES | 0.00000 | 1.75951 | 2.39938 |
| LEV | -1.75951 | 0.00000 | 0.63987 |
| ASC | -2.39938 | -0.63987 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34442

| Abs(Dif)-LSD | DES | LEV | ASC |
|---|---|---|---|
| DES | -1.7074 | 0.4945 | -5.6543 |
| LEV | 0.4945 | -0.5341 | -7.3317 |
| ASC | -5.6543 | -7.3317 | -11.2609 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 10 | 4.34581 | 2.462836 | 1.686380 |
| DES | 435 | 7.53227 | 4.073409 | 3.830838 |
| LEV | 4446 | 11.01258 | 5.357557 | 5.209377 |

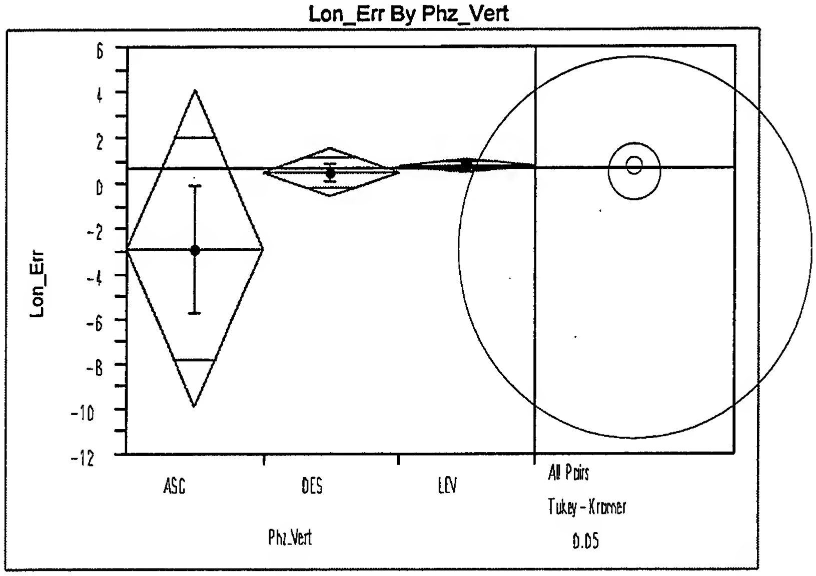
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 1.9542 | 2 | 4888 | 0.1418 |
| Brown-Forsythe | 4.8354 | 2 | 4888 | 0.0080 |
| Levene | 4.1621 | 2 | 4888 | 0.0156 |
| Bartlett | 49.9821 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 9.7795 | 2 | 24.222 | 0.0008 |

**Figure A.1- 166 Statistical Tests for Lateral Error and Vertical Phase of Flight at Look Ahead Time 1800 for Samples at Altitudes Above 18,000 Feet**

Lon_Err By Phz_Vert




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 10 | -2.92582 | 9.2215 | 2.9161 |
| DES | 435 | 0.54567 | 9.4178 | 0.4516 |
| LEV | 4446 | 0.80756 | 11.5720 | 0.1735 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | LEV | DES | ASC |
|---|---|---|---|
| LEV | 0.00000 | 0.26189 | 3.73338 |
| DES | -0.26189 | 0.00000 | 3.47149 |
| ASC | -3.73338 | -3.47149 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34442

| Abs(Dif)-LSD | LEV | DES | ASC |
|---|---|---|---|
| LEV | -0.5665 | -1.0800 | -4.7227 |
| DES | -1.0800 | -1.8111 | -5.0717 |
| ASC | -4.7227 | -5.0717 | -11.9453 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

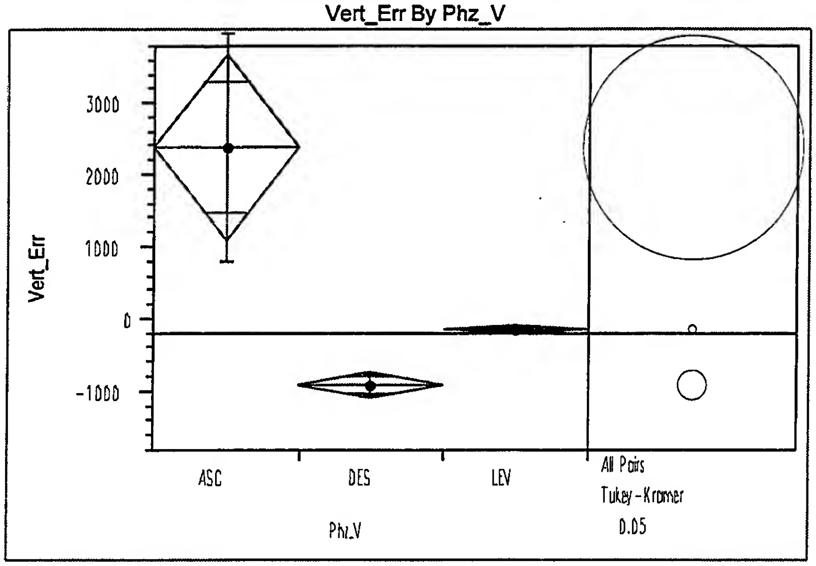
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 10 | 9.22151 | 7.537656 | 7.346080 |
| DES | 435 | 9.41785 | 6.429918 | 6.428583 |
| LEV | 4446 | 11.57197 | 7.704713 | 7.703998 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 2.4490 | 2 | 4888 | 0.0865 |
| Brown-Forsythe | 4.4769 | 2 | 4888 | 0.0114 |
| Levene | 4.4709 | 2 | 4888 | 0.0115 |
| Bartlett | 15.0694 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 0.9230 | 2 | 23.771 | 0.4111 |

**Figure A.1- 167 Statistical Tests for Longitudinal Error and Vertical Phase of Flight at Look Ahead Time 1800 for Samples at Altitudes Above 18,000 Feet**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 10 | 2414.28 | 5061.16 | 1600.5 |
| DES | 435 | -891.51 | 3299.07 | 158.2 |
| LEV | 4446 | -116.41 | 1966.69 | 29.5 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | ASC | LEV | DES |
|---|---|---|---|
| ASC | 0.00 | 2530.69 | 3305.79 |
| LEV | -2530.69 | 0.00 | 775.10 |
| DES | -3305.79 | -775.10 | 0.00 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34442

| Abs(Dif)-LSD | ASC | LEV | DES |
|---|---|---|---|
| ASC | -2231.72 | 950.85 | 1709.69 |
| LEV | 950.85 | -105.84 | 524.40 |
| DES | 1709.69 | 524.40 | -338.37 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 10 | 5061.157 | 2952.446 | 2267.479 |
| DES | 435 | 3299.071 | 2467.997 | 2467.877 |
| LEV | 4446 | 1966.689 | 795.071 | 721.228 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 12.7046 | 2 | 4888 | <.0001 |
| Brown-Forsythe | 174.2590 | 2 | 4888 | <.0001 |
| Levene | 169.1966 | 2 | 4888 | <.0001 |
| Bartlett | 150.7959 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 12.5235 | 2 | 23.559 | 0.0002 |

**Figure A.1- 168 Statistical Tests for Vertical Error and Vertical Phase of Flight at Look Ahead Time 1800 for Samples at Altitudes Above 18,000 Feet**

# A.2 CTAS

## *A.2.1 Look Ahead Time*

### A.2.1.1 Summary Tables

| Look Ahead Time (sec) | 0 | 300 | 600 | 900 | 1200 | 1500 | 1800 |
|---|---|---|---|---|---|---|---|
| Sample Quantity | 32609 | 27163 | 21908 | 16941 | 12921 | 9261 | 6657 |
| Avg. Horz. Error | 0.28 | 2.64 | 4.53 | 6.21 | 7.82 | 9.4 | 10.94 |
| Stddev. Horz. Error | 0.85 | 3.19 | 4.95 | 6.56 | 8.12 | 9.76 | 11.22 |
| Max. Horz. Error | 48.02 | 88.45 | 67.08 | 101.09 | 103.04 | 94.14 | 98.82 |
| Min. Horz. Error | 0 | 0 | 0.01 | 0.01 | 0.01 | 0.03 | 0.03 |
| Avg. Lat. Error | 0 | 0.03 | 0.24 | 0.46 | 0.56 | 0.46 | 0.46 |
| Stddev. Lat. Error | 0.45 | 3.3 | 5.03 | 6.33 | 7.46 | 8.55 | 9.39 |
| Max. Lat. Error | 22.88 | 46.61 | 55.5 | 60.84 | 76.1 | 85.67 | 86.54 |
| Min. Lat. Error | -15.57 | -46.12 | -38.27 | -64.27 | -55.56 | -65.63 | -62.21 |
| Avg. Abs. Lat. Error | 0.13 | 1.73 | 2.66 | 3.33 | 3.92 | 4.42 | 4.87 |
| Stddev. Abs. Lat. Error | 0.44 | 2.81 | 4.28 | 5.41 | 6.37 | 7.34 | 8.05 |
| Max. Abs. Lat. Error | 22.88 | 46.61 | 55.5 | 64.27 | 76.1 | 85.67 | 86.54 |
| Min. Abs. Lat. Error | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Avg. Long. Error | -0.05 | -0.06 | 0.29 | 0.64 | 1.19 | 1.86 | 2.43 |
| Stddev. Long. Error | 0.77 | 2.5 | 4.43 | 6.39 | 8.35 | 10.34 | 12.3 |
| Max. Long. Error | 47.54 | 46.01 | 59.63 | 58.31 | 77.59 | 94.14 | 96.86 |
| Min. Long. Error | -31.16 | -87.99 | -59.56 | -83.04 | -94.35 | -73.71 | -78.6 |
| Avg. Abs. Long. Error | 0.21 | 1.48 | 2.83 | 4.14 | 5.46 | 6.79 | 8.13 |
| Stddev. Abs. Long. Error | 0.74 | 2.01 | 3.42 | 4.92 | 6.43 | 8.01 | 9.54 |
| Max. Abs. Long. Error | 47.54 | 87.99 | 59.63 | 83.04 | 94.35 | 94.14 | 96.86 |
| Min. Abs. Long. Error | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Avg. Vert. Error | -98.82 | -527.89 | -759.82 | -912.93 | -1053.07 | -1151.01 | -1266.59 |
| Stddev. Vert. Error | 789.35 | 2159.92 | 2844.69 | 3359.14 | 3580.43 | 3697.21 | 3868.81 |
| Max. Vert. Error | 18889 | 27290 | 28990 | 29003 | 29003 | 29003 | 29003 |
| Min. Vert. Error | -31466.5 | -24677 | -26868 | -32426 | -28868 | -27901 | -29635 |
| Avg. Abs. Vert. Error | 154 | 1061.62 | 1503.76 | 1785.4 | 1940.87 | 2028.25 | 2163.38 |
| Stddev. Abs. Vert. Error | 780.46 | 1953.68 | 2531.44 | 2988.23 | 3187.68 | 3298.5 | 3448.37 |
| Max. Abs. Vert. Error | 31466.46 | 27290 | 28990 | 32426 | 29003 | 29003 | 29635 |
| Min. Abs. Vert. Error | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Avg. Slant Range Error | 0.28 | 2.67 | 4.56 | 6.25 | 7.86 | 9.44 | 10.98 |
| Stddev. Slant Range Error | 0.86 | 3.19 | 4.95 | 6.55 | 8.1 | 9.74 | 11.2 |
| Max. Slant Range Error | 48.03 | 88.56 | 67.09 | 101.09 | 103.05 | 94.14 | 98.82 |
| Min. Slant Range Error | 0 | 0.01 | 0.01 | 0.01 | 0.01 | 0.03 | 0.03 |

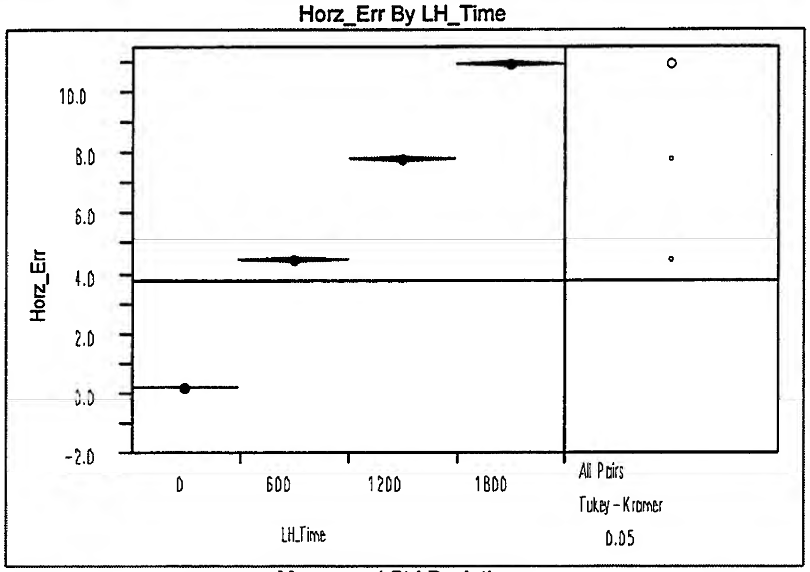
**Figure A.2- 1 Descriptive Statistics for Look Ahead Times 0 to 1800 Seconds from All Samples**

| Look Ahead Time (sec) | 0 | 300 | 600 | 900 | 1200 | 1500 | 1800 |
|---|---|---|---|---|---|---|---|
| Sample Quantity | 21209 | 18451 | 14807 | 11217 | 8189 | 5705 | 3917 |
| Avg. Horz. Error | 0.25 | 2.5 | 4.41 | 6.13 | 7.79 | 9.13 | 10.34 |
| Stddev. Horz. Error | 0.75 | 3.31 | 5.16 | 6.77 | 8.43 | 9.83 | 11.08 |
| Max. Horz. Error | 48.02 | 88.45 | 67.08 | 75.25 | 86.73 | 87.22 | 87.65 |
| Min. Horz. Error | 0 | 0 | 0.01 | 0.01 | 0.01 | 0.03 | 0.03 |
| Avg. Lat. Error | 0 | 0.06 | 0.33 | 0.66 | 0.86 | 0.76 | 0.71 |
| Stddev. Lat. Error | 0.41 | 3.46 | 5.36 | 6.9 | 8.25 | 9.49 | 10.33 |
| Max. Lat. Error | 22.88 | 46.61 | 55.5 | 60.84 | 76.1 | 85.67 | 86.54 |
| Min. Lat. Error | -15.57 | -46.12 | -38.27 | -43.96 | -55.56 | -65.63 | -62.21 |
| Avg. Abs. Lat. Error | 0.11 | 1.71 | 2.72 | 3.54 | 4.27 | 4.82 | 5.24 |
| Stddev. Abs. Lat. Error | 0.4 | 3.01 | 4.63 | 5.96 | 7.11 | 8.21 | 8.93 |
| Max. Abs. Lat. Error | 22.88 | 46.61 | 55.5 | 60.84 | 76.1 | 85.67 | 86.54 |
| Min. Abs. Lat. Error | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Avg. Long. Error | -0.04 | 0.04 | 0.31 | 0.43 | 0.7 | 0.8 | 0.84 |
| Stddev. Long. Error | 0.68 | 2.3 | 4.13 | 5.92 | 7.9 | 9.42 | 11.05 |
| Max. Long. Error | 47.54 | 46.01 | 59.63 | 58.31 | 77.59 | 63.91 | 77.47 |
| Min. Long. Error | -31.16 | -87.99 | -29.72 | -61.99 | -85.87 | -61.99 | -58.65 |
| Avg. Abs. Long. Error | 0.19 | 1.32 | 2.6 | 3.8 | 5.06 | 6.09 | 7.06 |
| Stddev. Abs. Long. Error | 0.65 | 1.88 | 3.23 | 4.56 | 6.11 | 7.23 | 8.54 |
| Max. Abs. Long. Error | 47.54 | 87.99 | 59.63 | 61.99 | 85.87 | 63.91 | 77.47 |
| Min. Abs. Long. Error | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Avg. Vert. Error | -17.45 | -143.41 | -284.9 | -267.38 | -201.11 | -180.72 | -128.9 |
| Stddev. Vert. Error | 499.6 | 1778.12 | 2594.45 | 3017.1 | 3061.06 | 2990.64 | 3058.47 |
| Max. Vert. Error | 18889 | 27290 | 28990 | 29003 | 29003 | 29003 | 29003 |
| Min. Vert. Error | -21500 | -18228 | -16708 | -20550 | -19633 | -20550 | -17851 |
| Avg. Abs. Vert. Error | 72.4 | 734.83 | 1177.4 | 1348.57 | 1343.89 | 1321.91 | 1359.03 |
| Stddev. Abs. Vert. Error | 494.63 | 1625.5 | 2329.37 | 2712.11 | 2757.59 | 2688.66 | 2742.89 |
| Max. Abs. Vert. Error | 21500 | 27290 | 28990 | 29003 | 29003 | 29003 | 29003 |
| Min. Abs. Vert. Error | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Avg. Slant Range Error | 0.25 | 2.52 | 4.44 | 6.16 | 7.82 | 9.16 | 10.36 |
| Stddev. Slant Range Error | 0.76 | 3.31 | 5.15 | 6.76 | 8.42 | 9.82 | 11.08 |
| Max. Slant Range Error | 48.03 | 88.56 | 67.09 | 75.4 | 86.86 | 87.23 | 87.65 |
| Min. Slant Range Error | 0 | 0.01 | 0.01 | 0.01 | 0.01 | 0.03 | 0.03 |

**Figure A.2- 2 Descriptive Statistics for Look Ahead Times 0 to 1800 Seconds from Samples at Altitudes Above 18,000 Feet**

### A.2.1.2 Statistical Tests

Horz_Err By LH_Time




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| 0 | 32609 | 0.2754 | 0.8489 | 0.00470 |
| 600 | 21908 | 4.5288 | 4.9547 | 0.03347 |
| 1200 | 12921 | 7.8219 | 8.1156 | 0.07140 |
| 1800 | 6657 | 10.9415 | 11.2172 | 0.13748 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | 1800 | 1200 | 600 | 0 |
|---|---|---|---|---|
| 1800 | 0.0000 | 3.1195 | 6.4127 | 10.6661 |
| 1200 | -3.1195 | 0.0000 | 3.2932 | 7.5466 |
| 600 | -6.4127 | -3.2932 | 0.0000 | 4.2534 |
| 0 | -10.6661 | -7.5466 | -4.2534 | 0.0000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.56909

| Abs(Dif)-LSD | 1800 | 1200 | 600 | 0 |
|---|---|---|---|---|
| 1800 | -0.2454 | 2.9059 | 6.2146 | 10.4757 |
| 1200 | 2.9059 | -0.1761 | 3.1361 | 7.3994 |
| 600 | 6.2146 | 3.1361 | -0.1353 | 4.1298 |
| 0 | 10.4757 | 7.3994 | 4.1298 | -0.1109 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

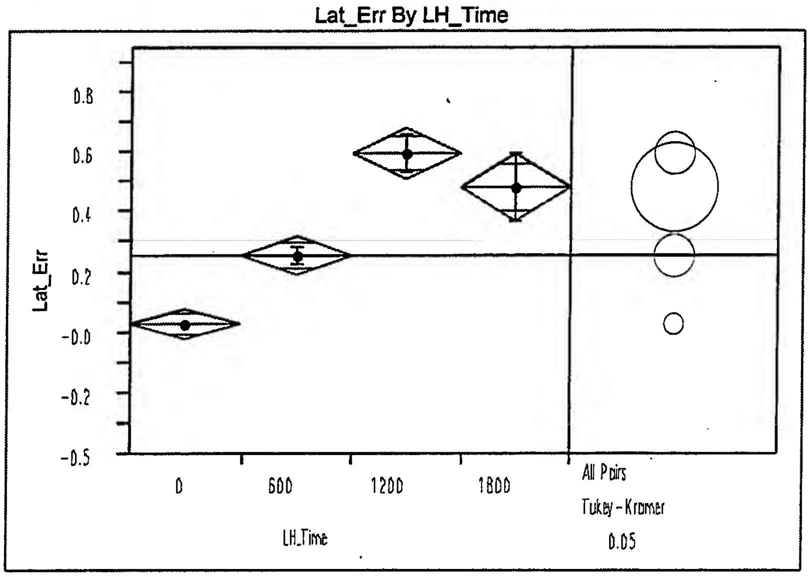
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| 0 | 32609 | 0.84893 | 0.248551 | 0.204254 |
| 600 | 21908 | 4.95467 | 3.452990 | 3.165135 |
| 1200 | 12921 | 8.11562 | 5.811963 | 5.382548 |
| 1800 | 6657 | 11.21723 | 8.211165 | 7.559329 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 1441.7847 | 3 | 74091 | 0.0000 |
| Brown-Forsythe | 7351.5399 | 3 | 74091 | 0.0000 |
| Levene | 11959.587 | 3 | 74091 | 0.0000 |
| Bartlett | 35722.914 | 3 | ? | 0.0000 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 10866.429 | 3 | 18479 | 0.0000 |

**Figure A.2- 3 Statistical Tests for Horizontal Error and Look Ahead Time for Samples at All Altitudes**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| 0 | 32609 | 0.000470 | 0.45435 | 0.00252 |
| 600 | 21908 | 0.236306 | 5.03038 | 0.03399 |
| 1200 | 12921 | 0.562154 | 7.45748 | 0.06561 |
| 1800 | 6657 | 0.456111 | 9.39249 | 0.11512 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | 1200 | 1800 | 600 | 0 |
|---|---|---|---|---|
| 1200 | 0.000000 | 0.106042 | 0.325848 | 0.561684 |
| 1800 | -0.10604 | 0.000000 | 0.219806 | 0.455641 |
| 600 | -0.32585 | -0.21981 | 0.000000 | 0.235835 |
| 0 | -0.56168 | -0.45564 | -0.23584 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.56909

| Abs(Dif)-LSD | 1200 | 1800 | 600 | 0 |
|---|---|---|---|---|
| 1200 | -0.16044 | -0.08851 | 0.182805 | 0.427630 |
| 1800 | -0.08851 | -0.22352 | 0.039329 | 0.282203 |
| 600 | 0.182805 | 0.039329 | -0.12321 | 0.123183 |
| 0 | 0.427630 | 0.282203 | 0.123183 | -0.10099 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

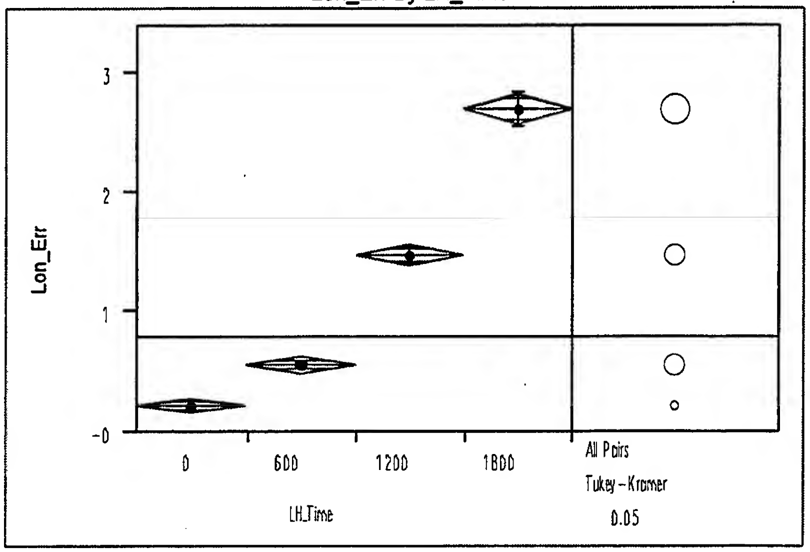
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| 0 | 32609 | 0.454348 | 0.126259 | 0.126242 |
| 600 | 21908 | 5.030381 | 2.691498 | 2.655372 |
| 1200 | 12921 | 7.457478 | 4.036750 | 3.915983 |
| 1800 | 6657 | 9.392486 | 4.945310 | 4.868303 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 905.7122 | 3 | 74091 | 0.0000 |
| Brown-Forsythe | 4096.1593 | 3 | 74091 | 0.0000 |
| Levene | 4374.2475 | 3 | 74091 | 0.0000 |
| Bartlett | 45998.4 | 3 | ? | 0.0000 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 45.4172 | 3 | 18354 | <.0001 |

**Figure A.2- 4 Statistical Tests for Lateral Error and Look Ahead Time for Samples at All Altitudes**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| 0 | 32609 | -0.04957 | 0.7666 | 0.00425 |
| 600 | 21908 | 0.29322 | 4.4286 | 0.02992 |
| 1200 | 12921 | 1.19392 | 8.3484 | 0.07344 |
| 1800 | 6657 | 2.42624 | 12.2982 | 0.15073 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | 1800 | 1200 | 600 | 0 |
|---|---|---|---|---|
| 1800 | 0.00000 | 1.23232 | 2.13302 | 2.47581 |
| 1200 | -1.23232 | 0.00000 | 0.90070 | 1.24349 |
| 600 | -2.13302 | -0.90070 | 0.00000 | 0.34279 |
| 0 | -2.47581 | -1.24349 | -0.34279 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.56909

| Abs(Dif)-LSD | 1800 | 1200 | 600 | 0 |
|---|---|---|---|---|
| 1800 | -0.25111 | 1.01375 | 1.93027 | 2.28096 |
| 1200 | 1.01375 | -0.18024 | 0.74001 | 1.09289 |
| 600 | 1.93027 | 0.74001 | -0.13842 | 0.21623 |
| 0 | 2.28096 | 1.09289 | 0.21623 | -0.11346 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| 0 | 32609 | 0.76656 | 0.204627 | 0.204534 |
| 600 | 21908 | 4.42865 | 2.824441 | 2.822935 |
| 1200 | 12921 | 8.34837 | 5.438772 | 5.416451 |
| 1800 | 6657 | 12.29819 | 8.178568 | 8.062229 |

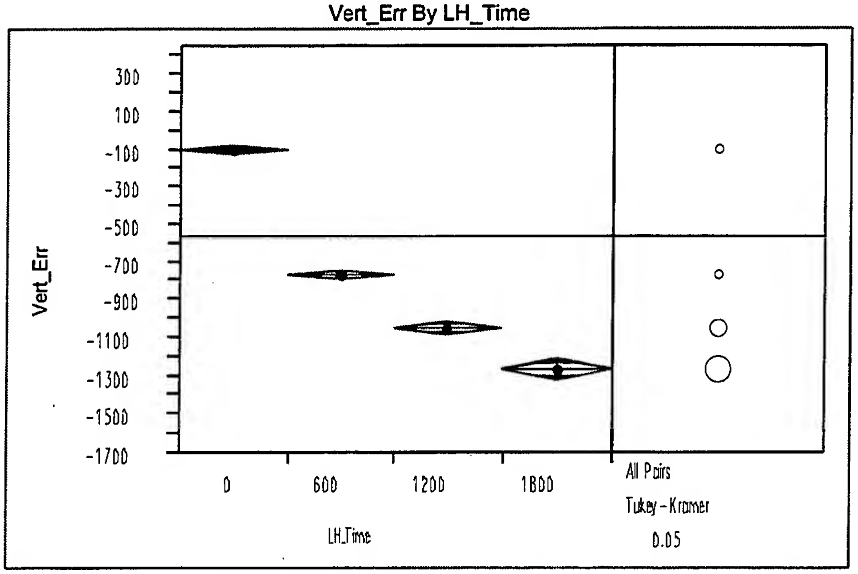
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 1945.4371 | 3 | 74091 | 0.0000 |
| Brown-Forsythe | 8726.3921 | 3 | 74091 | 0.0000 |
| Levene | 9121.9444 | 3 | 74091 | 0.0000 |
| Bartlett | 40068.356 | 3 | ? | 0.0000 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 226.1604 | 3 | 18464 | <.0001 |

**Figure A.2- 5 Statistical Tests for Longitudinal Error and Look Ahead Time for Samples at All Altitudes**

Vert_Err By LH_Time




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| 0 | 32609 | -98.82 | 789.35 | 4.371 |
| 600 | 21908 | -759.82 | 2844.69 | 19.219 |
| 1200 | 12921 | -1053.07 | 3580.43 | 31.498 |
| 1800 | 6657 | -1266.59 | 3868.81 | 47.417 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | 0 | 600 | 1200 | 1800 |
|---|---|---|---|---|
| 0 | 0.00 | 661.00 | 954.25 | 1167.76 |
| 600 | -661.00 | 0.00 | 293.25 | 506.76 |
| 1200 | -954.25 | -293.25 | 0.00 | 213.51 |
| 1800 | -1167.76 | -506.76 | -213.51 | 0.00 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.56909

| Abs(Dif)-LSD | 0 | 600 | 1200 | 1800 |
|---|---|---|---|---|
| 0 | -50.29 | 604.91 | 887.50 | 1081.40 |
| 600 | 604.91 | -61.35 | 222.03 | 416.90 |
| 1200 | 887.50 | 222.03 | -79.89 | 116.64 |
| 1800 | 1081.40 | 416.90 | 116.64 | -111.30 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

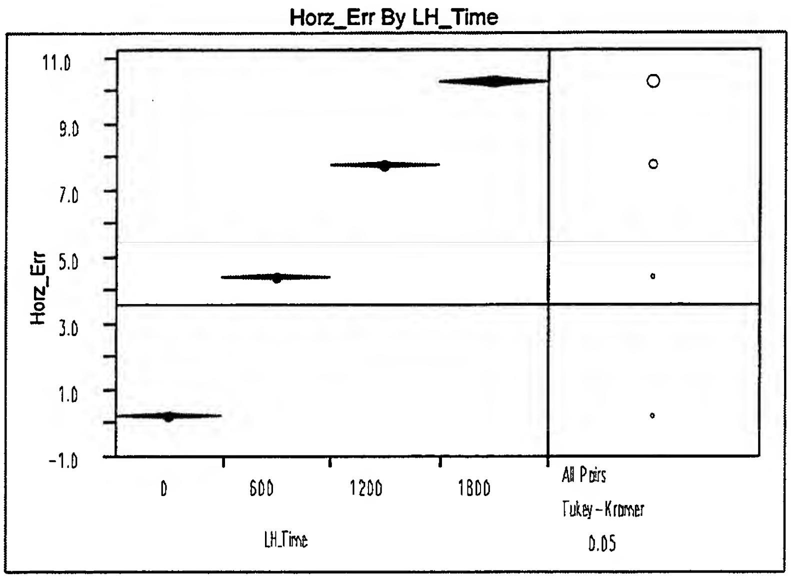
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| 0 | 32609 | 789.350 | 204.724 | 154.004 |
| 600 | 21908 | 2844.690 | 1804.238 | 1503.764 |
| 1200 | 12921 | 3580.432 | 2324.048 | 1940.867 |
| 1800 | 6657 | 3868.811 | 2619.756 | 2163.376 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 928.7413 | 3 | 74091 | 0.0000 |
| Brown-Forsythe | 3277.6670 | 3 | 74091 | 0.0000 |
| Levene | 6270.1902 | 3 | 74091 | 0.0000 |
| Bartlett | 18130.9 | 3 | ? | 0.0000 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 839.2193 | 3 | 18933 | 0.0000 |

**Figure A.2- 6 Statistical Tests for Vertical Error and Look Ahead Time for Samples at All Altitudes**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| 0 | 21209 | 0.2490 | 0.7535 | 0.00517 |
| 600 | 14807 | 4.4124 | 5.1550 | 0.04236 |
| 1200 | 8189 | 7.7915 | 8.4267 | 0.09312 |
| 1800 | 3917 | 10.3445 | 11.0827 | 0.17708 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | 1800 | 1200 | 600 | 0 |
|---|---|---|---|---|
| 1800 | 0.0000 | 2.5529 | 5.9321 | 10.0955 |
| 1200 | -2.5529 | 0.0000 | 3.3792 | 7.5426 |
| 600 | -5.9321 | -3.3792 | 0.0000 | 4.1634 |
| 0 | -10.0955 | -7.5426 | -4.1634 | 0.0000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.56912

| Abs(Dif)-LSD | 1800 | 1200 | 600 | 0 |
|---|---|---|---|---|
| 1800 | -0.32064 | 2.27728 | 5.67716 | 9.84875 |
| 1200 | 2.27728 | -0.22176 | 3.18375 | 7.35797 |
| 600 | 5.67716 | 3.18375 | -0.16492 | 4.01146 |
| 0 | 9.84875 | 7.35797 | 4.01146 | -0.13780 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| 0 | 21209 | 0.75354 | 0.210933 | 0.176164 |
| 600 | 14807 | 5.15501 | 3.514434 | 3.163892 |
| 1200 | 8189 | 8.42674 | 5.973631 | 5.476191 |
| 1800 | 3917 | 11.08267 | 7.862517 | 7.195796 |

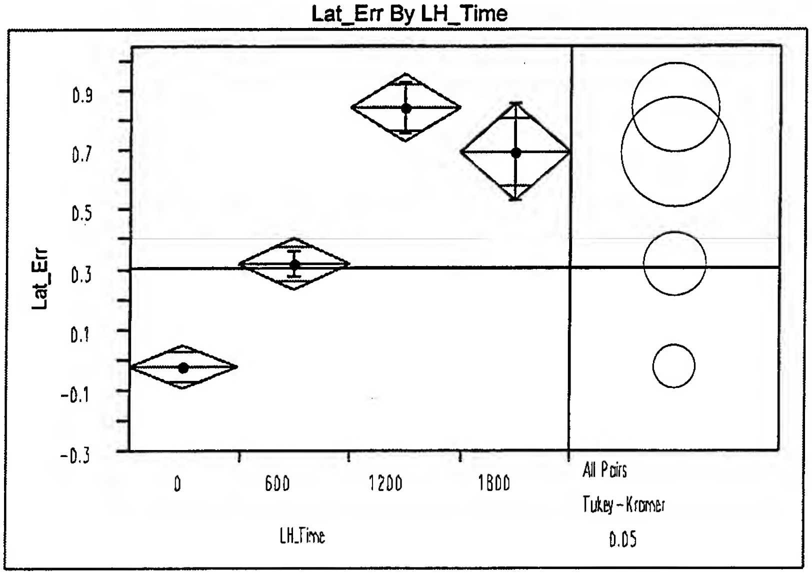
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 900.7762 | 3 | 48118 | 0.0000 |
| Brown-Forsythe | 4300.1517 | 3 | 48118 | 0.0000 |
| Levene | 7114.4988 | 3 | 48118 | 0.0000 |
| Bartlett | 24719.234 | 3 | ? | 0.0000 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 6381.0736 | 3 | 11314 | 0.0000 |

**Figure A.2- 7 Statistical Tests for Horizontal Error and Look Ahead Time for Samples at Altitudes Above 18,000 Feet**

Lat_Err By LH_Time




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| 0 | 21209 | -0.00108 | 0.4117 | 0.00283 |
| 600 | 14807 | 0.328630 | 5.3616 | 0.04406 |
| 1200 | 8189 | 0.863553 | 8.2486 | 0.09115 |
| 1800 | 3917 | 0.709525 | 10.3269 | 0.16500 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | 1200 | 1800 | 600 | 0 |
|---|---|---|---|---|
| 1200 | 0.000000 | 0.154027 | 0.534923 | 0.864633 |
| 1800 | -0.15403 | 0.000000 | 0.380895 | 0.710606 |
| 600 | -0.53492 | -0.3809 | 0.000000 | 0.329711 |
| 0 | -0.86463 | -0.71061 | -0.32971 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.56912

| Abs(Dif)-LSD | 1200 | 1800 | 600 | 0 |
|---|---|---|---|---|
| 1200 | -0.21687 | -0.11557 | 0.343812 | 0.684086 |
| 1800 | -0.11557 | -0.31358 | 0.131553 | 0.469264 |
| 600 | 0.343812 | 0.131553 | -0.16128 | 0.181096 |
| 0 | 0.684086 | 0.469264 | 0.181096 | -0.13476 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

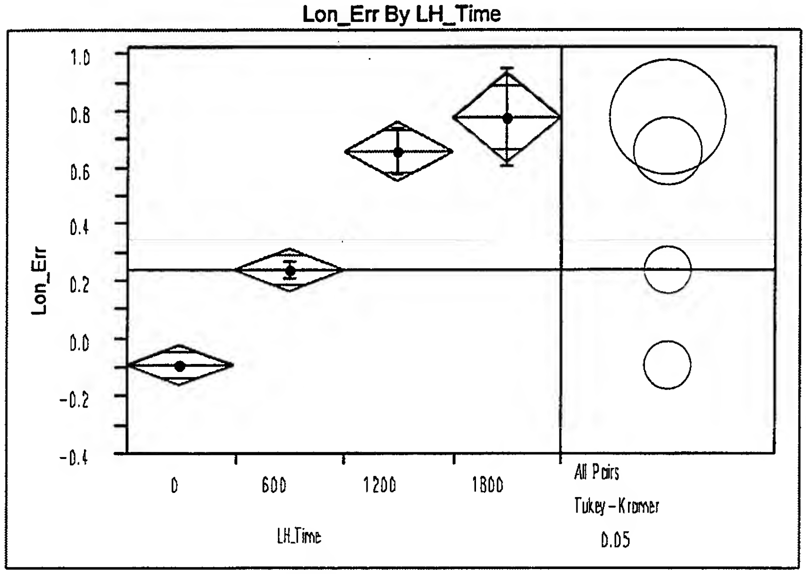
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| 0 | 21209 | 0.41171 | 0.109176 | 0.109164 |
| 600 | 14807 | 5.36156 | 2.795106 | 2.723243 |
| 1200 | 8189 | 8.24865 | 4.504469 | 4.269265 |
| 1800 | 3917 | 10.32692 | 5.417549 | 5.240543 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 625.0230 | 3 | 48118 | 0.0000 |
| Brown-Forsythe | 2556.2337 | 3 | 48118 | 0.0000 |
| Levene | 2893.7115 | 3 | 48118 | 0.0000 |
| Bartlett | 32463.712 | 3 | ? | 0.0000 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 54.5945 | 3 | 11259 | <.0001 |

**Figure A.2- 8 Statistical Tests for Lateral Error and Look Ahead Time for Samples at Altitudes Above 18,000 Feet**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| 0 | 21209 | -0.04456 | 0.6770 | 0.00465 |
| 600 | 14807 | 0.312483 | 4.1343 | 0.03398 |
| 1200 | 8189 | 0.702831 | 7.9022 | 0.08732 |
| 1800 | 3917 | 0.835682 | 11.0460 | 0.17649 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | 1800 | 1200 | 600 | 0 |
|---|---|---|---|---|
| 1800 | 0.000000 | 0.132851 | 0.523199 | 0.880243 |
| 1200 | -0.13285 | 0.000000 | 0.390348 | 0.747392 |
| 600 | -0.5232 | -0.39035 | 0.000000 | 0.357044 |
| 0 | -0.88024 | -0.74739 | -0.35704 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.56912

| Abs(Dif)-LSD | 1800 | 1200 | 600 | 0 |
|---|---|---|---|---|
| 1800 | -0.29611 | -0.12173 | 0.287746 | 0.652345 |
| 1200 | -0.12173 | -0.20479 | 0.209883 | 0.576902 |
| 600 | 0.287746 | 0.209883 | -0.1523 | 0.216708 |
| 0 | 0.652345 | 0.576902 | 0.216708 | -0.12725 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| 0 | 21209 | 0.67698 | 0.187322 | 0.187311 |
| 600 | 14807 | 4.13431 | 2.597534 | 2.592815 |
| 1200 | 8189 | 7.90224 | 5.063641 | 5.050070 |
| 1800 | 3917 | 11.04599 | 7.078687 | 7.051549 |

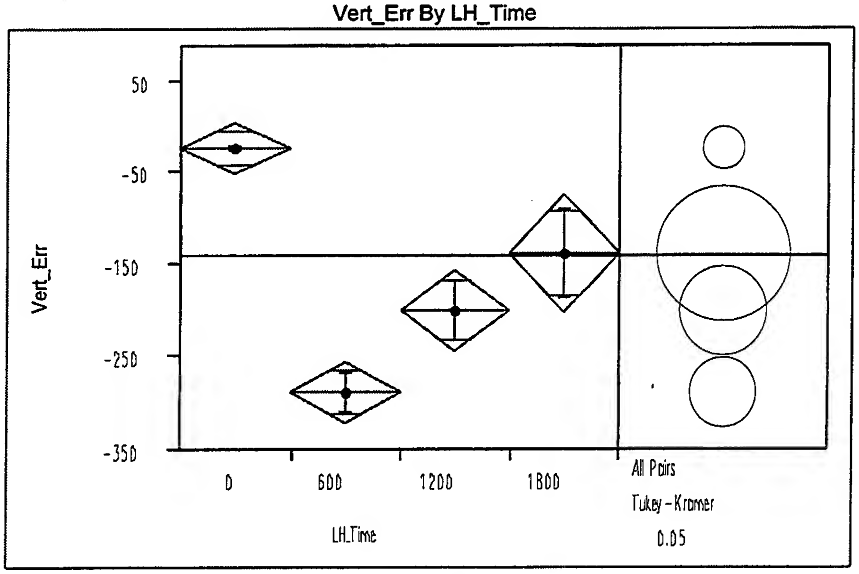
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 1085.1001 | 3 | 48118 | 0.0000 |
| Brown-Forsythe | 5259.6511 | 3 | 48118 | 0.0000 |
| Levene | 5338.1311 | 3 | 48118 | 0.0000 |
| Bartlett | 26218.094 | 3 | ? | 0.0000 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 68.1760 | 3 | 11323 | <.0001 |

**Figure A.2- 9 Statistical Tests for Longitudinal Error and Look Ahead Time for Samples at Altitudes Above 18,000 Feet**

Vert_Err By LH_Time




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| 0 | 21209 | -17.448 | 499.60 | 3.431 |
| 600 | 14807 | -284.905 | 2594.45 | 21.321 |
| 1200 | 8189 | -201.113 | 3061.06 | 33.826 |
| 1800 | 3917 | -128.899 | 3058.47 | 48.868 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | 0 | 1800 | 1200 | 600 |
|---|---|---|---|---|
| 0 | 0.000 | 111.450 | 183.664 | 267.456 |
| 1800 | -111.450 | 0.000 | 72.214 | 156.006 |
| 1200 | -183.664 | -72.214 | 0.000 | 83.792 |
| 600 | -267.456 | -156.006 | -83.792 | 0.000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.56912

| Abs(Dif)-LSD | 0 | 1800 | 1200 | 600 |
|---|---|---|---|---|
| 0 | -53.140 | 16.282 | 112.469 | 208.853 |
| 1800 | 16.282 | -123.653 | -34.096 | 57.683 |
| 1200 | 112.469 | -34.096 | -85.520 | 8.431 |
| 600 | 208.853 | 57.683 | 8.431 | -63.599 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| 0 | 21209 | 499.596 | 83.588 | 72.401 |
| 600 | 14807 | 2594.446 | 1335.927 | 1177.396 |
| 1200 | 8189 | 3061.063 | 1461.372 | 1343.885 |
| 1800 | 3917 | 3058.472 | 1438.069 | 1359.031 |

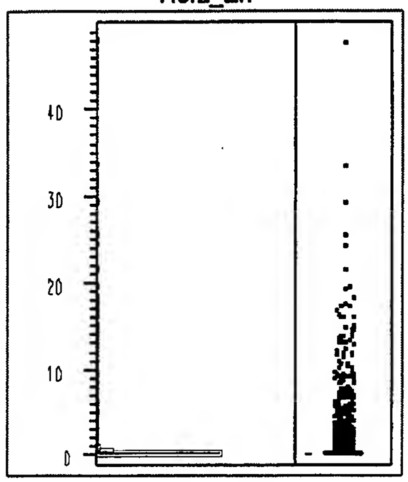
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 409.7103 | 3 | 48118 | <.0001 |
| Brown-Forsythe | 1517.5682 | 3 | 48118 | 0.0000 |
| Levene | 1960.3021 | 3 | 48118 | 0.0000 |
| Bartlett | 15630.425 | 3 | ? | 0.0000 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 61.6208 | 3 | 11442 | <.0001 |

**Figure A.2- 10 Statistical Tests for Vertical Error and Look Ahead Time for Samples at Altitudes Above 18,000 Feet**

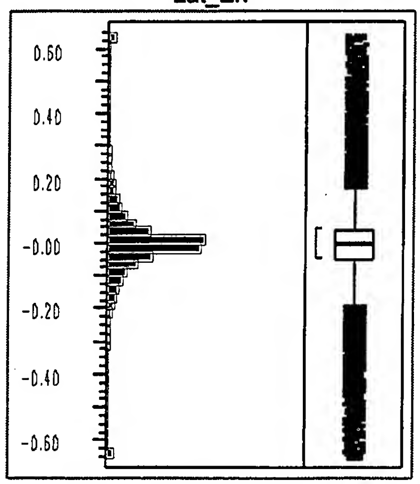
### A.2.1.3 Histograms




| | Quantiles | |
|---|---|---|
| maximum | 100.0% | 48.025 |
| | 99.5% | 4.158 |
| | 97.5% | 1.081 |
| | 90.0% | 0.508 |
| quartile | 75.0% | 0.266 |
| median | 50.0% | 0.135 |
| quartile | 25.0% | 0.073 |
| | 10.0% | 0.033 |
| | 2.5% | 0.005 |
| | 0.5% | 0.002 |
| minimum | 0.0% | 0.000 |

| Moments | |
|---|---|
| Mean | 0.28 |
| Std Dev | 0.85 |
| Std Error Mean | 0.00 |
| Upper 95% Mean | 0.28 |
| Lower 95% Mean | 0.27 |
| N | 32559.00 |
| Sum Weights | 32559.00 |

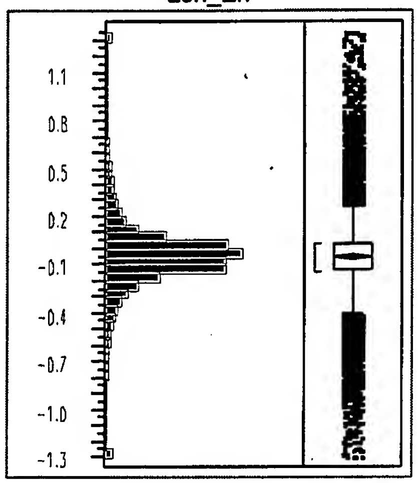
**Figure A.2- 11 Histogram and Quantile for Horizontal Error and Look Ahead Time 0 for Samples at All Altitudes**




| | Quantiles | |
|---|---|---|
| maximum | 100.0% | 22.878 |
| | 99.5% | 1.382 |
| | 97.5% | 0.403 |
| | 90.0% | 0.139 |
| quartile | 75.0% | 0.043 |
| median | 50.0% | -0.000 |
| quartile | 25.0% | -0.048 |
| | 10.0% | -0.150 |
| | 2.5% | -0.424 |
| | 0.5% | -1.278 |
| minimum | 0.0% | -15.570 |

| Moments | |
|---|---|
| Mean | 0.00 |
| Std Dev | 0.45 |
| Std Error Mean | 0.00 |
| Upper 95% Mean | 0.01 |
| Lower 95% Mean | -0.00 |
| N | 32559.00 |
| Sum Weights | 32559.00 |

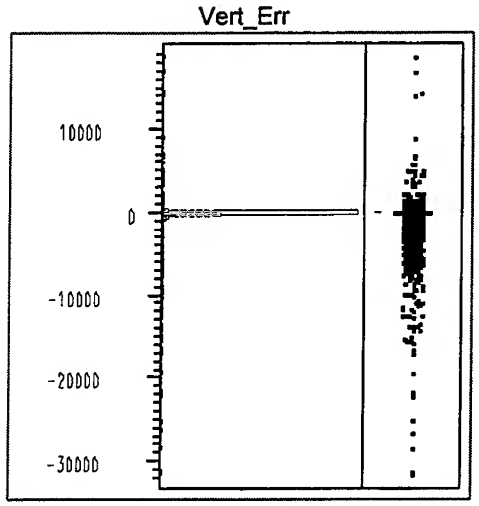
**Figure A.2- 12 Histogram and Quantile for Lateral Error and Look Ahead Time 0 for Samples at All Altitudes**




| | Quantiles | |
|---|---|---|
| maximum | 100.0% | 47.539 |
| | 99.5% | 1.477 |
| | 97.5% | 0.567 |
| | 90.0% | 0.190 |
| quartile | 75.0% | 0.037 |
| median | 50.0% | -0.044 |
| quartile | 25.0% | -0.134 |
| | 10.0% | -0.279 |
| | 2.5% | -0.634 |
| | 0.5% | -1.838 |
| minimum | 0.0% | -31.165 |

| Moments | |
|---|---|
| Mean | -0.05 |
| Std Dev | 0.77 |
| Std Error Mean | 0.00 |
| Upper 95% Mean | -0.04 |
| Lower 95% Mean | -0.06 |
| N | 32559.00 |
| Sum Weights | 32559.00 |

**Figure A.2- 13 Histogram and Quantile for Longitudinal Error and Look Ahead Time 0 for Samples at All Altitudes**



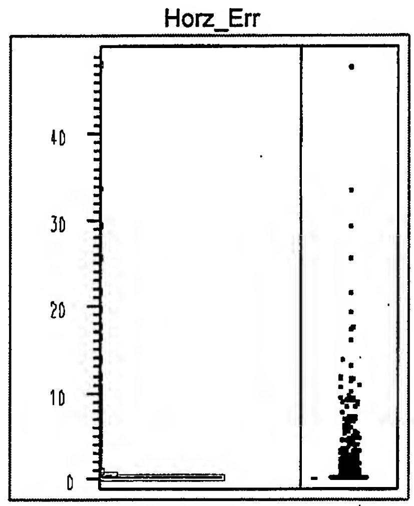

Quantiles

| | | |
|---|---|---|
| maximum | 100.0% | 18889 |
| | 99.5% | 553 |
| | 97.5% | 195 |
| | 90.0% | 93 |
| quartile | 75.0% | 0 |
| median | 50.0% | 0 |
| quartile | 25.0% | -42 |
| | 10.0% | -201 |
| | 2.5% | -866 |
| | 0.5% | -4311 |
| minimum | 0.0% | -31467 |

Moments

| | |
|---|---|
| Mean | -98.73 |
| Std Dev | 788.43 |
| Std Error Mean | 4.37 |
| Upper 95% Mean | -90.16 |
| Lower 95% Mean | -107.29 |
| N | 32559.00 |
| Sum Weights | 32559.00 |

**Figure A.2- 14 Histogram and Quantile for Vertical Error and Look Ahead Time 0 for Samples at All Altitudes**



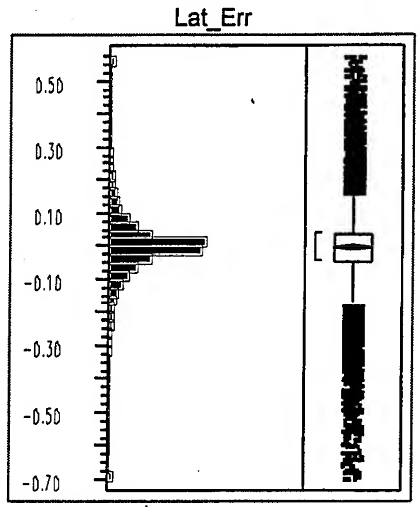

Quantiles

| | | |
|---|---|---|
| maximum | 100.0% | 48.025 |
| | 99.5% | 2.855 |
| | 97.5% | 0.919 |
| | 90.0% | 0.495 |
| quartile | 75.0% | 0.253 |
| median | 50.0% | 0.134 |
| quartile | 25.0% | 0.077 |
| | 10.0% | 0.033 |
| | 2.5% | 0.005 |
| | 0.5% | 0.002 |
| minimum | 0.0% | 0.000 |

Moments

| | |
|---|---|
| Mean | 0.25 |
| Std Dev | 0.75 |
| Std Error Mean | 0.01 |
| Upper 95% Mean | 0.26 |
| Lower 95% Mean | 0.24 |
| N | 21165.00 |
| Sum Weights | 21165.00 |

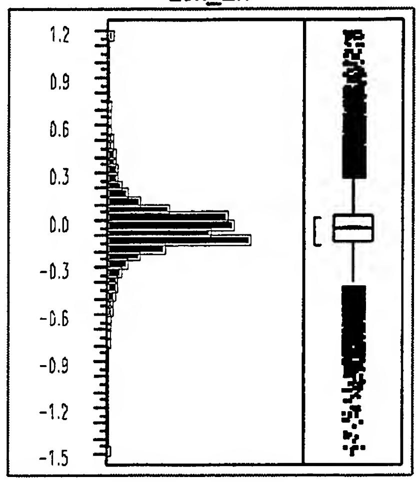
**Figure A.2- 15 Histogram and Quantile for Horizontal Error and Look Ahead Time 0 for Samples at Altitudes Above 18,000 Feet**




| | Quantiles | |
|---|---|---|
| maximum | 100.0% | 22.878 |
| | 99.5% | 0.856 |
| | 97.5% | 0.354 |
| | 90.0% | 0.127 |
| quartile | 75.0% | 0.040 |
| median | 50.0% | -0.000 |
| quartile | 25.0% | -0.045 |
| | 10.0% | -0.136 |
| | 2.5% | -0.368 |
| | 0.5% | -0.992 |
| minimum | 0.0% | -15.570 |

| Moments | |
|---|---|
| Mean | -0.00 |
| Std Dev | 0.41 |
| Std Error Mean | 0.00 |
| Upper 95% Mean | 0.00 |
| Lower 95% Mean | -0.01 |
| N | 21165.00 |
| Sum Weights | 21165.00 |

**Figure A.2- 16 Histogram and Quantile for Lateral Error and Look Ahead Time 0 for Samples at Altitudes Above 18,000 Feet**



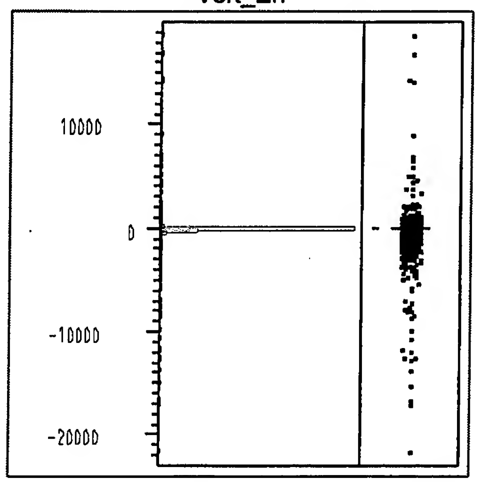

Quantiles

| | | |
|---|---|---|
| maximum | 100.0% | 47.539 |
| | 99.5% | 1.278 |
| | 97.5% | 0.575 |
| | 90.0% | 0.181 |
| quartile | 75.0% | 0.037 |
| median | 50.0% | -0.047 |
| quartile | 25.0% | -0.136 |
| | 10.0% | -0.263 |
| | 2.5% | -0.605 |
| | 0.5% | -1.118 |
| minimum | 0.0% | -31.165 |

Moments

| | |
|---|---|
| Mean | -0.04 |
| Std Dev | 0.68 |
| Std Error Mean | 0.00 |
| Upper 95% Mean | -0.04 |
| Lower 95% Mean | -0.05 |
| N | 21165.00 |
| Sum Weights | 21165.00 |

**Figure A.2- 17 Histogram and Quantile for Longitudinal Error and Look Ahead Time 0 for Samples at Altitudes Above 18,000 Feet**




Quantiles

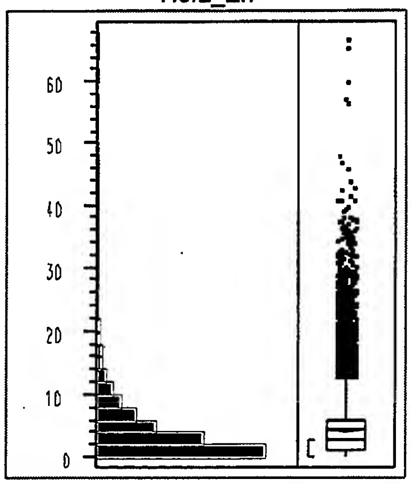
| | | |
|---|---|---|
| maximum | 100.0% | 18889 |
| | 99.5% | 563 |
| | 97.5% | 196 |
| | 90.0% | 67 |
| quartile | 75.0% | 0 |
| median | 50.0% | 0 |
| quartile | 25.0% | 0 |
| | 10.0% | -100 |
| | 2.5% | -292 |
| | 0.5% | -1125 |
| minimum | 0.0% | -21500 |

Moments

| | |
|---|---|
| Mean | -17.53 |
| Std Dev | 500.09 |
| Std Error Mean | 3.44 |
| Upper 95% Mean | -10.79 |
| Lower 95% Mean | -24.27 |
| N | 21165.00 |
| Sum Weights | 21165.00 |

**Figure A.2- 18 Histogram and Quantile for Vertical Error and Look Ahead Time 0 for Samples at Altitudes Above 18,000 Feet**

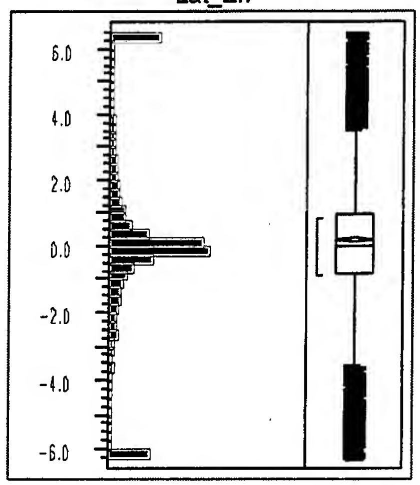
Horz_Err




| | Quantiles | |
|---|---|---|
| maximum | 100.0% | 67.078 |
| | 99.5% | 28.331 |
| | 97.5% | 18.050 |
| | 90.0% | 10.460 |
| quartile | 75.0% | 6.078 |
| median | 50.0% | 2.851 |
| quartile | 25.0% | 1.304 |
| | 10.0% | 0.599 |
| | 2.5% | 0.230 |
| | 0.5% | 0.094 |
| minimum | 0.0% | 0.012 |

| Moments | |
|---|---|
| Mean | 4.53 |
| Std Dev | 4.95 |
| Std Error Mean | 0.03 |
| Upper 95% Mean | 4.59 |
| Lower 95% Mean | 4.46 |
| N | 21879.00 |
| Sum Weights | 21879.00 |

**Figure A.2- 19 Histogram and Quantile for Horizontal Error and Look Ahead Time 600 for Samples at All Altitudes**



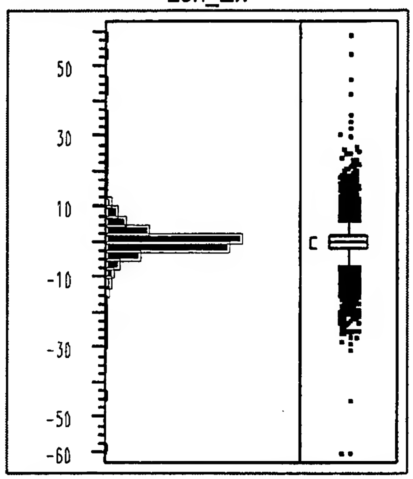

Quantiles

| | | |
|---|---|---|
| maximum | 100.0% | 55.499 |
| | 99.5% | 22.137 |
| | 97.5% | 12.308 |
| | 90.0% | 4.611 |
| quartile | 75.0% | 0.975 |
| median | 50.0% | -0.001 |
| quartile | 25.0% | -0.820 |
| | 10.0% | -3.807 |
| | 2.5% | -9.991 |
| | 0.5% | -19.225 |
| minimum | 0.0% | -38.275 |

Moments

| | |
|---|---|
| Mean | 0.24 |
| Std Dev | 5.03 |
| Std Error Mean | 0.03 |
| Upper 95% Mean | 0.30 |
| Lower 95% Mean | 0.17 |
| N | 21879.00 |
| Sum Weights | 21879.00 |

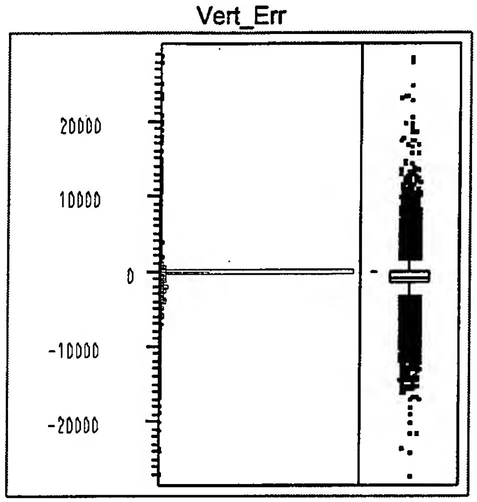
**Figure A.2- 20 Histogram and Quantile for Lateral Error and Look Ahead Time 600 for Samples at All Altitudes**




| | Quantiles | |
|---|---|---|
| maximum | 100.0% | 59.630 |
| | 99.5% | 16.290 |
| | 97.5% | 9.523 |
| | 90.0% | 4.909 |
| quartile | 75.0% | 1.945 |
| median | 50.0% | 0.204 |
| quartile | 25.0% | -1.359 |
| | 10.0% | -3.911 |
| | 2.5% | -9.361 |
| | 0.5% | -15.604 |
| minimum | 0.0% | -59.561 |

| Moments | |
|---|---|
| Mean | 0.29 |
| Std Dev | 4.43 |
| Std Error Mean | 0.03 |
| Upper 95% Mean | 0.35 |
| Lower 95% Mean | 0.24 |
| N | 21879.00 |
| Sum Weights | 21879.00 |

**Figure A.2- 21 Histogram and Quantile for Longitudinal Error and Look Ahead Time 600 for Samples at All Altitudes**

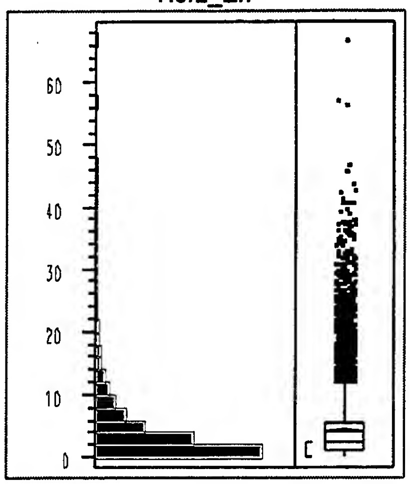



| | Quantiles | |
|---|---|---|
| maximum | 100.0% | 28990 |
| | 99.5% | 9362 |
| | 97.5% | 4200 |
| | 90.0% | 680 |
| quartile | 75.0% | 0 |
| median | 50.0% | 0 |
| quartile | 25.0% | -1264 |
| | 10.0% | -4210 |
| | 2.5% | -7683 |
| | 0.5% | -11096 |
| minimum | 0.0% | -26868 |

| Moments | |
|---|---|
| Mean | -759.30 |
| Std Dev | 2843.26 |
| Std Error Mean | 19.22 |
| Upper 95% Mean | -721.62 |
| Lower 95% Mean | -796.97 |
| N | 21879.00 |
| Sum Weights | 21879.00 |

**Figure A.2- 22 Histogram and Quantile for Vertical Error and Look Ahead Time 600 for Samples at All Altitudes**

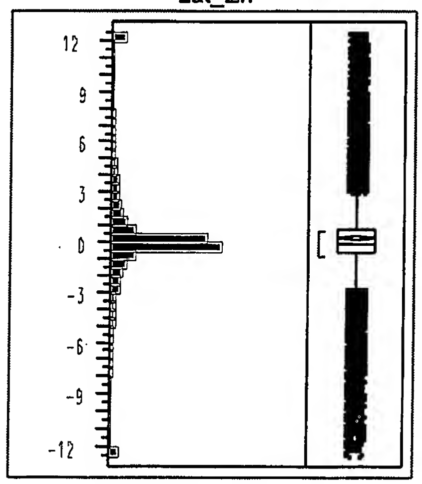
Horz_Err




| | Quantiles | |
|---|---|---|
| maximum | 100.0% | 67.078 |
| | 99.5% | 30.332 |
| | 97.5% | 18.932 |
| | 90.0% | 10.476 |
| quartile | 75.0% | 5.697 |
| median | 50.0% | 2.618 |
| quartile | 25.0% | 1.191 |
| | 10.0% | 0.542 |
| | 2.5% | 0.209 |
| | 0.5% | 0.078 |
| minimum | 0.0% | 0.012 |

| Moments | |
|---|---|
| Mean | 4.41 |
| Std Dev | 5.16 |
| Std Error Mean | 0.04 |
| Upper 95% Mean | 4.50 |
| Lower 95% Mean | 4.33 |
| N | 14781.00 |
| Sum Weights | 14781.00 |

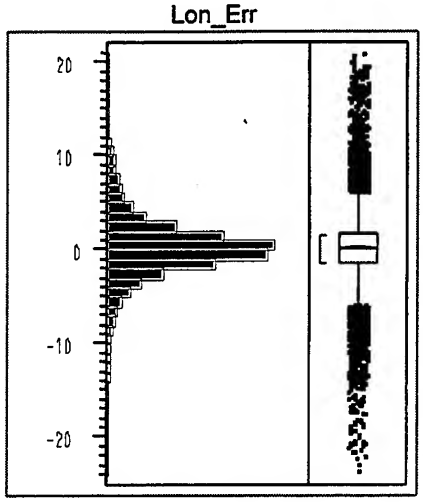
**Figure A.2- 23 Histogram and Quantile for Horizontal Error and Look Ahead Time 600 for Samples at Altitudes Above 18,000 Feet**




| | Quantiles | |
|---|---|---|
| maximum | 100.0% | 55.499 |
| | 99.5% | 25.207 |
| | 97.5% | 13.303 |
| | 90.0% | 4.808 |
| quartile | 75.0% | 0.875 |
| median | 50.0% | -0.001 |
| quartile | 25.0% | -0.589 |
| | 10.0% | -3.741 |
| | 2.5% | -10.708 |
| | 0.5% | -20.190 |
| minimum | 0.0% | -38.275 |

| Moments | |
|---|---|
| Mean | 0.33 |
| Std Dev | 5.36 |
| Std Error Mean | 0.04 |
| Upper 95% Mean | 0.41 |
| Lower 95% Mean | 0.24 |
| N | 14781.00 |
| Sum Weights | 14781.00 |

**Figure A.2- 24 Histogram and Quantile for Lateral Error and Look Ahead Time 600 for Samples at Altitudes Above 18,000 Feet**

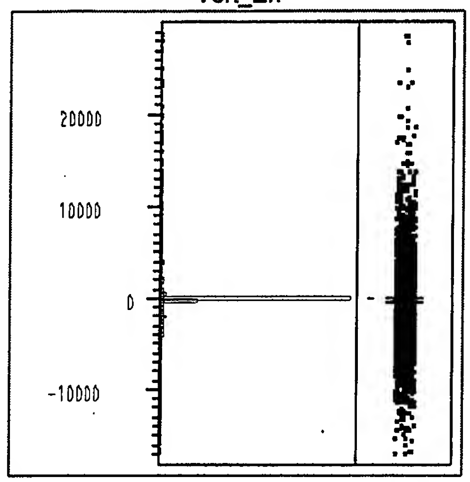



| | Quantiles | |
|---|---|---|
| maximum | 100.0% | 59.630 |
| | 99.5% | 17.181 |
| | 97.5% | 9.452 |
| | 90.0% | 4.290 |
| quartile | 75.0% | 1.737 |
| median | 50.0% | 0.164 |
| quartile | 25.0% | -1.309 |
| | 10.0% | -3.449 |
| | 2.5% | -8.064 |
| | 0.5% | -13.862 |
| minimum | 0.0% | -29.720 |

| Moments | |
|---|---|
| Mean | 0.32 |
| Std Dev | 4.13 |
| Std Error Mean | 0.03 |
| Upper 95% Mean | 0.38 |
| Lower 95% Mean | 0.25 |
| N | 14781.00 |
| Sum Weights | 14781.00 |

**Figure A.2- 25 Histogram and Quantile for Longitudinal Error and Look Ahead Time 600 for Samples at Altitudes Above 18,000 Feet**

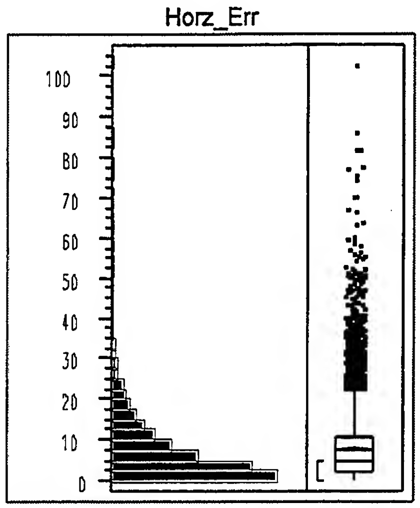
Vert_Err




| | Quantiles | |
|---|---|---|
| maximum | 100.0% | 28990 |
| | 99.5% | 10602 |
| | 97.5% | 4810 |
| | 90.0% | 1000 |
| quartile | 75.0% | 0 |
| median | 50.0% | 0 |
| quartile | 25.0% | -19 |
| | 10.0% | -3083 |
| | 2.5% | -6588 |
| | 0.5% | -10171 |
| minimum | 0.0% | -16708 |

| Moments | |
|---|---|
| Mean | -285.52 |
| Std Dev | 2596.63 |
| Std Error Mean | 21.36 |
| Upper 95% Mean | -243.66 |
| Lower 95% Mean | -327.39 |
| N | 14781.00 |
| Sum Weights | 14781.00 |

**Figure A.2- 26 Histogram and Quantile for Vertical Error and Look Ahead Time 600 for Samples at Altitudes Above 18,000 Feet**




Quantiles

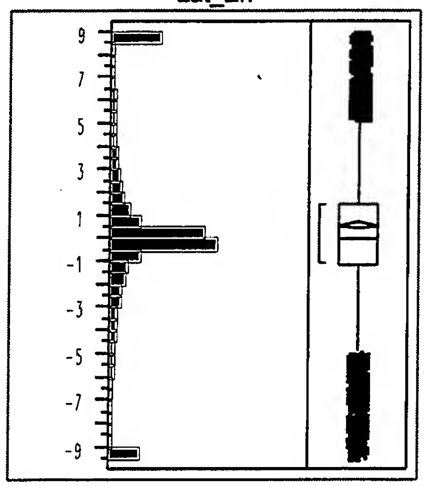
| | | |
|---|---|---|
| maximum | 100.0% | 103.04 |
| | 99.5% | 45.67 |
| | 97.5% | 28.82 |
| | 90.0% | 18.21 |
| quartile | 75.0% | 10.68 |
| median | 50.0% | 5.08 |
| quartile | 25.0% | 2.36 |
| | 10.0% | 1.11 |
| | 2.5% | 0.40 |
| | 0.5% | 0.15 |
| minimum | 0.0% | 0.01 |

Moments

| | |
|---|---|
| Mean | 7.82 |
| Std Dev | 8.12 |
| Std Error Mean | 0.07 |
| Upper 95% Mean | 7.96 |
| Lower 95% Mean | 7.68 |
| N | 12906.00 |
| Sum Weights | 12906.00 |

**Figure A.2- 27 Histogram and Quantile for Horizontal Error and Look Ahead Time 1200 for Samples at All Altitudes**

Lat_Err



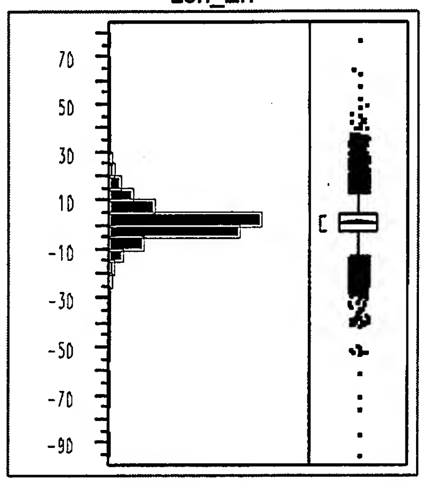

Quantiles

| | | |
|---|---|---|
| maximum | 100.0% | 76.097 |
| | 99.5% | 31.484 |
| | 97.5% | 19.275 |
| | 90.0% | 7.327 |
| quartile | 75.0% | 1.434 |
| median | 50.0% | 0.003 |
| quartile | 25.0% | -1.103 |
| | 10.0% | -5.291 |
| | 2.5% | -13.911 |
| | 0.5% | -27.595 |
| minimum | 0.0% | -55.557 |

Moments

| | |
|---|---|
| Mean | 0.56 |
| Std Dev | 7.46 |
| Std Error Mean | 0.07 |
| Upper 95% Mean | 0.69 |
| Lower 95% Mean | 0.43 |
| N | 12906.00 |
| Sum Weights | 12906.00 |

**Figure A.2- 28 Histogram and Quantile for Lateral Error and Look Ahead Time 1200 for Samples at All Altitudes**




Quantiles

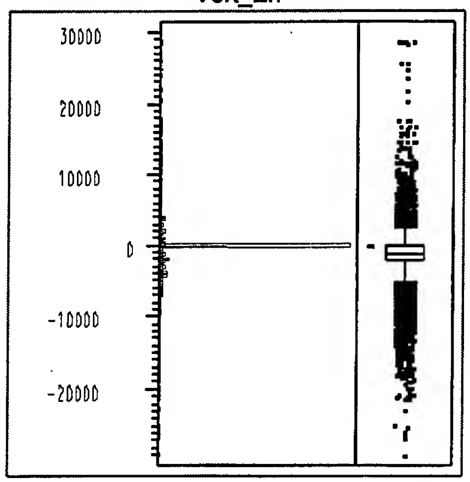
| | | |
|---|---|---|
| maximum | 100.0% | 77.593 |
| | 99.5% | 33.079 |
| | 97.5% | 20.209 |
| | 90.0% | 10.599 |
| quartile | 75.0% | 4.145 |
| median | 50.0% | 0.678 |
| quartile | 25.0% | -2.332 |
| | 10.0% | -6.634 |
| | 2.5% | -14.954 |
| | 0.5% | -25.366 |
| minimum | 0.0% | -94.354 |

Moments

| | |
|---|---|
| Mean | 1.20 |
| Std Dev | 8.35 |
| Std Error Mean | 0.07 |
| Upper 95% Mean | 1.34 |
| Lower 95% Mean | 1.05 |
| N | 12906.00 |
| Sum Weights | 12906.00 |

**Figure A.2- 29 Histogram and Quantile for Longitudinal Error and Look Ahead Time 1200 for Samples at All Altitudes**

Vert_Err



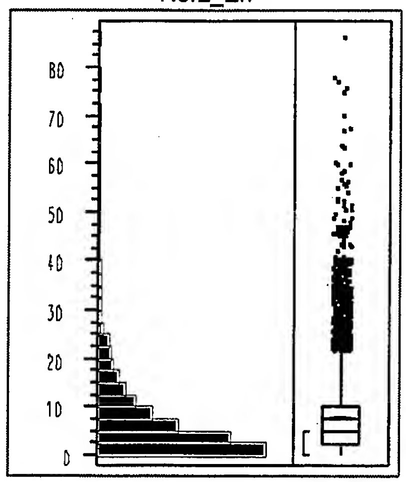

Quantiles

| | | |
|---|---|---|
| maximum | 100.0% | 29003 |
| | 99.5% | 11400 |
| | 97.5% | 4996 |
| | 90.0% | 894 |
| quartile | 75.0% | 0 |
| median | 50.0% | 0 |
| quartile | 25.0% | -2000 |
| | 10.0% | -5533 |
| | 2.5% | -9956 |
| | 0.5% | -15000 |
| minimum | 0.0% | -28868 |

Moments

| | |
|---|---|
| Mean | -1054.38 |
| Std Dev | 3582.30 |
| Std Error Mean | 31.53 |
| Upper 95% Mean | -992.57 |
| Lower 95% Mean | -1116.19 |
| N | 12906.00 |
| Sum Weights | 12906.00 |

**Figure A.2- 30 Histogram and Quantile for Vertical Error and Look Ahead Time 1200 for Samples at All Altitudes**

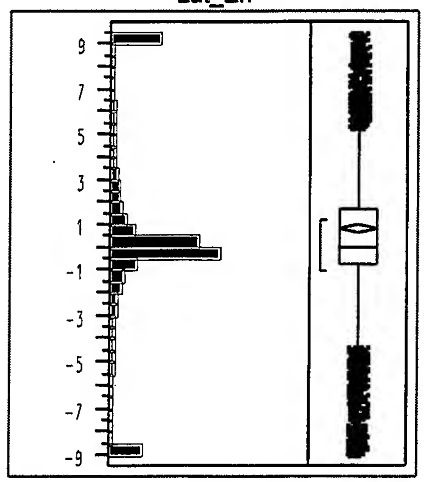



| | Quantiles | |
|---|---|---|
| maximum | 100.0% | 86.730 |
| | 99.5% | 46.966 |
| | 97.5% | 31.471 |
| | 90.0% | 18.739 |
| quartile | 75.0% | 10.329 |
| median | 50.0% | 4.878 |
| quartile | 25.0% | 2.239 |
| | 10.0% | 1.022 |
| | 2.5% | 0.356 |
| | 0.5% | 0.152 |
| minimum | 0.0% | 0.010 |

| Moments | |
|---|---|
| Mean | 7.793 |
| Std Dev | 8.433 |
| Std Error Mean | 0.093 |
| Upper 95% Mean | 7.976 |
| Lower 95% Mean | 7.610 |
| N | 8174.000 |
| Sum Weights | 8174.000 |

**Figure A.2- 31 Histogram and Quantile for Horizontal Error and Look Ahead Time 1200 for Samples at Altitudes Above 18,000 Feet**

Lat_Err



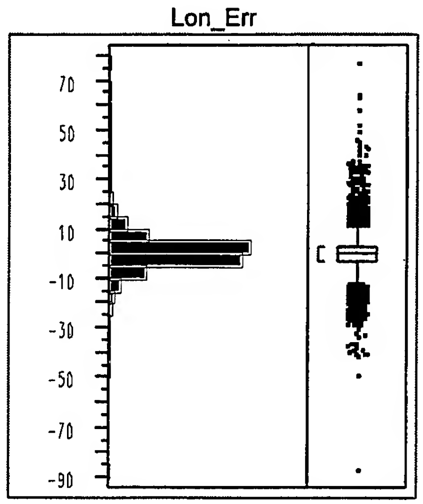

Quantiles

| | | |
|---|---|---|
| maximum | 100.0% | 76.097 |
| | 99.5% | 38.178 |
| | 97.5% | 20.816 |
| | 90.0% | 8.617 |
| quartile | 75.0% | 1.685 |
| median | 50.0% | 0.012 |
| quartile | 25.0% | -0.725 |
| | 10.0% | -5.491 |
| | 2.5% | -15.418 |
| | 0.5% | -29.866 |
| minimum | 0.0% | -55.557 |

Moments

| | |
|---|---|
| Mean | 0.864 |
| Std Dev | 8.254 |
| Std Error Mean | 0.091 |
| Upper 95% Mean | 1.043 |
| Lower 95% Mean | 0.685 |
| N | 8174.000 |
| Sum Weights | 8174.000 |

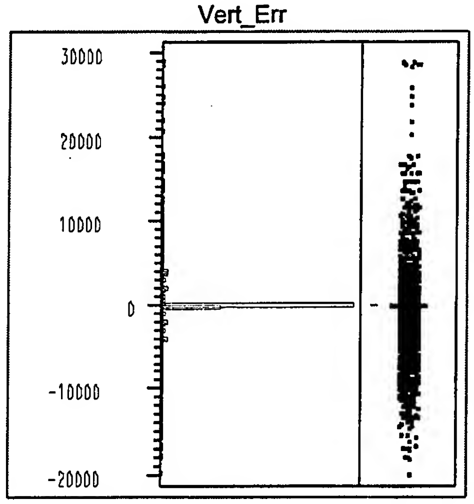
**Figure A.2- 32 Histogram and Quantile for Lateral Error and Look Ahead Time 1200 for Samples at Altitudes Above 18,000 Feet**




| | Quantiles | |
|---|---|---|
| maximum | 100.0% | 77.593 |
| | 99.5% | 34.644 |
| | 97.5% | 18.449 |
| | 90.0% | 8.733 |
| quartile | 75.0% | 3.429 |
| median | 50.0% | 0.314 |
| quartile | 25.0% | -2.606 |
| | 10.0% | -6.633 |
| | 2.5% | -14.938 |
| | 0.5% | -25.017 |
| minimum | 0.0% | -85.873 |

| Moments | |
|---|---|
| Mean | 0.710 |
| Std Dev | 7.904 |
| Std Error Mean | 0.087 |
| Upper 95% Mean | 0.881 |
| Lower 95% Mean | 0.538 |
| N | 8174.000 |
| Sum Weights | 8174.000 |

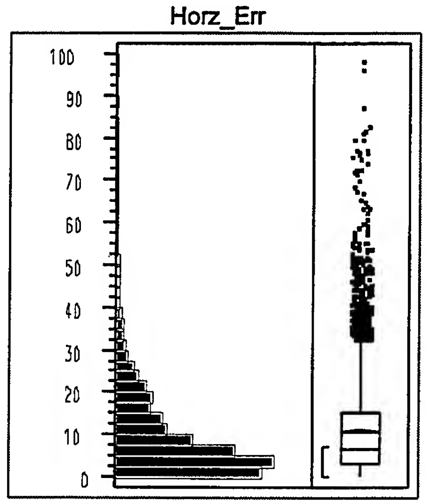
**Figure A.2- 33 Histogram and Quantile for Longitudinal Error and Look Ahead Time 1200 for Samples at Altitudes Above 18,000 Feet**




| | Quantiles | |
|---|---|---|
| maximum | 100.0% | 29003 |
| | 99.5% | 13987 |
| | 97.5% | 5998 |
| | 90.0% | 1990 |
| quartile | 75.0% | 0 |
| median | 50.0% | 0 |
| quartile | 25.0% | -12 |
| | 10.0% | -3328 |
| | 2.5% | -7014 |
| | 0.5% | -11663 |
| minimum | 0.0% | -19633 |

| Moments | |
|---|---|
| Mean | -201.604 |
| Std Dev | 3063.830 |
| Std Error Mean | 33.888 |
| Upper 95% Mean | -135.174 |
| Lower 95% Mean | -268.035 |
| N | 8174.000 |
| Sum Weights | 8174.000 |

**Figure A.2- 34 Histogram and Quantile for Vertical Error and Look Ahead Time 1200 for Samples at Altitudes Above 18,000 Feet**




Quantiles

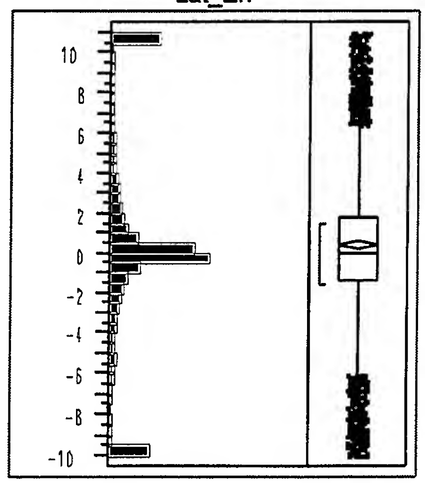
| | | |
|---|---|---|
| maximum | 100.0% | 98.819 |
| | 99.5% | 60.160 |
| | 97.5% | 41.289 |
| | 90.0% | 25.177 |
| quartile | 75.0% | 15.152 |
| median | 50.0% | 6.972 |
| quartile | 25.0% | 3.265 |
| | 10.0% | 1.511 |
| | 2.5% | 0.539 |
| | 0.5% | 0.202 |
| minimum | 0.0% | 0.033 |

Moments

| | |
|---|---|
| Mean | 10.944 |
| Std Dev | 11.221 |
| Std Error Mean | 0.138 |
| Upper 95% Mean | 11.214 |
| Lower 95% Mean | 10.674 |
| N | 6652.000 |
| Sum Weights | 6652.000 |

Figure A.2- 35 Histogram and Quantile for Horizontal Error and Look Ahead Time 1800 for Samples at All Altitudes

Lat_Err



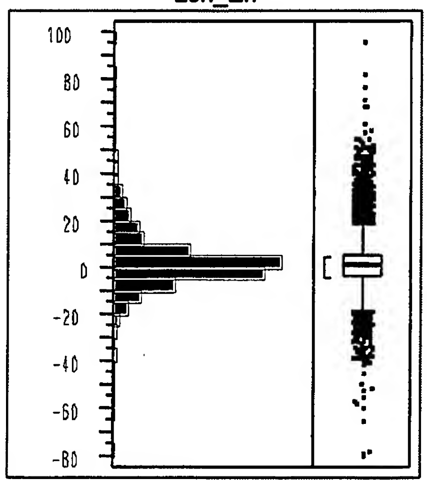

Quantiles

| | | |
|---|---|---|
| maximum | 100.0% | 86.540 |
| | 99.5% | 38.179 |
| | 97.5% | 20.862 |
| | 90.0% | 8.903 |
| quartile | 75.0% | 1.800 |
| median | 50.0% | 0.001 |
| quartile | 25.0% | -1.327 |
| | 10.0% | -6.680 |
| | 2.5% | -19.617 |
| | 0.5% | -36.906 |
| minimum | 0.0% | -62.208 |

Moments

| | |
|---|---|
| Mean | 0.455 |
| Std Dev | 9.395 |
| Std Error Mean | 0.115 |
| Upper 95% Mean | 0.681 |
| Lower 95% Mean | 0.229 |
| N | 6652.000 |
| Sum Weights | 6652.000 |

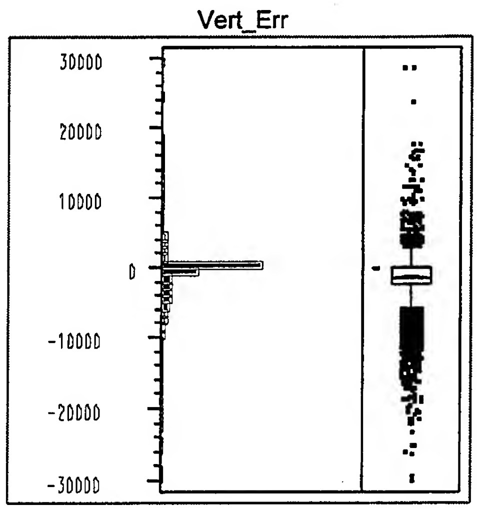
**Figure A.2- 36 Histogram and Quantile for Lateral Error and Look Ahead Time 1800 for Samples at All Altitudes**




| | Quantiles | |
|---|---|---|
| maximum | 100.0% | 96.864 |
| | 99.5% | 50.147 |
| | 97.5% | 32.840 |
| | 90.0% | 17.798 |
| quartile | 75.0% | 6.068 |
| median | 50.0% | 1.039 |
| quartile | 25.0% | -3.394 |
| | 10.0% | -9.044 |
| | 2.5% | -19.133 |
| | 0.5% | -36.379 |
| minimum | 0.0% | -78.603 |

| Moments | |
|---|---|
| Mean | 2.433 |
| Std Dev | 12.300 |
| Std Error Mean | 0.151 |
| Upper 95% Mean | 2.728 |
| Lower 95% Mean | 2.137 |
| N | 6652.000 |
| Sum Weights | 6652.000 |

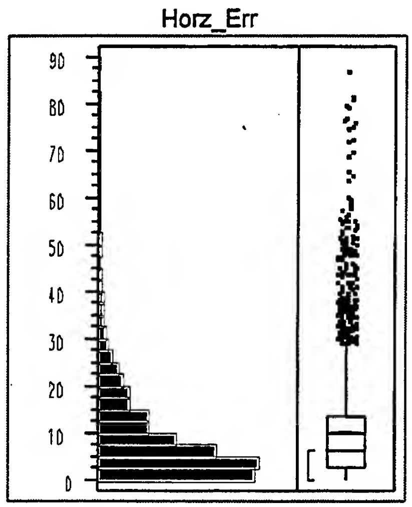
**Figure A.2- 37 Histogram and Quantile for Longitudinal Error and Look Ahead Time 1800 for Samples at All Altitudes**




| | Quantiles | |
|---|---|---|
| maximum | 100.0% | 29003 |
| | 99.5% | 10171 |
| | 97.5% | 4183 |
| | 90.0% | 1000 |
| quartile | 75.0% | 0 |
| median | 50.0% | 0 |
| quartile | 25.0% | -2217 |
| | 10.0% | -6283 |
| | 2.5% | -11092 |
| | 0.5% | -16573 |
| minimum | 0.0% | -29635 |

| Moments | |
|---|---|
| Mean | -1267.540 |
| Std Dev | 3870.108 |
| Std Error Mean | 47.451 |
| Upper 95% Mean | -1174.519 |
| Lower 95% Mean | -1360.561 |
| N | 6652.000 |
| Sum Weights | 6652.000 |

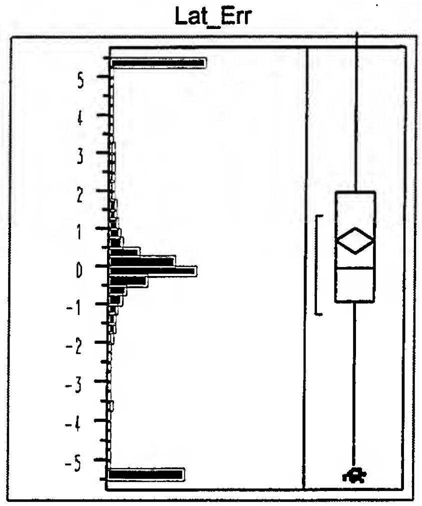
**Figure A.2- 38 Histogram and Quantile for Vertical Error and Look Ahead Time 1800 for Samples at All Altitudes**




| | Quantiles | |
|---|---|---|
| maximum | 100.0% | 87.650 |
| | 99.5% | 59.734 |
| | 97.5% | 43.374 |
| | 90.0% | 23.817 |
| quartile | 75.0% | 13.729 |
| median | 50.0% | 6.567 |
| quartile | 25.0% | 3.048 |
| | 10.0% | 1.401 |
| | 2.5% | 0.476 |
| | 0.5% | 0.167 |
| minimum | 0.0% | 0.033 |

| Moments | |
|---|---|
| Mean | 10.348 |
| Std Dev | 11.088 |
| Std Error Mean | 0.177 |
| Upper 95% Mean | 10.696 |
| Lower 95% Mean | 10.001 |
| N | 3912.000 |
| Sum Weights | 3912.000 |

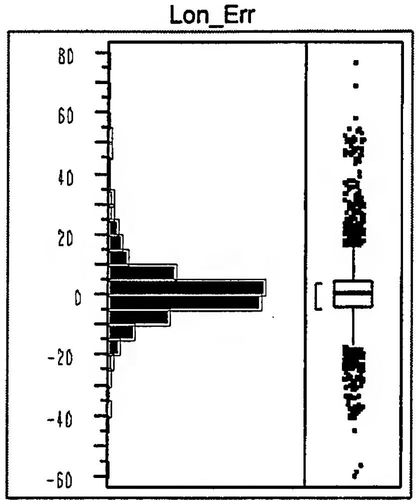
**Figure A.2- 39 Histogram and Quantile for Horizontal Error and Look Ahead Time 1800 for Samples at Altitudes Above 18,000 Feet**




| Quantiles | | |
|---|---|---|
| maximum | 100.0% | 86.540 |
| | 99.5% | 49.046 |
| | 97.5% | 21.972 |
| | 90.0% | 10.498 |
| quartile | 75.0% | 1.948 |
| median | 50.0% | -0.004 |
| quartile | 25.0% | -0.898 |
| | 10.0% | -7.210 |
| | 2.5% | -21.145 |
| | 0.5% | -42.319 |
| minimum | 0.0% | -62.208 |

| Moments | |
|---|---|
| Mean | 0.708 |
| Std Dev | 10.332 |
| Std Error Mean | 0.165 |
| Upper 95% Mean | 1.032 |
| Lower 95% Mean | 0.384 |
| N | 3912.000 |
| Sum Weights | 3912.000 |

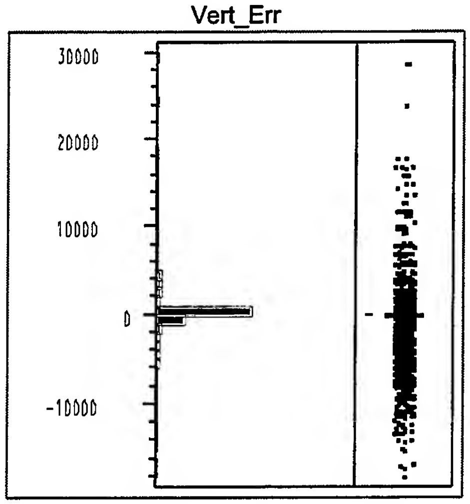
**Figure A.2- 40 Histogram and Quantile for Lateral Error and Look Ahead Time 1800 for Samples at Altitudes Above 18,000 Feet**




| | Quantiles | |
|---|---|---|
| maximum | 100.0% | 77.472 |
| | 99.5% | 51.686 |
| | 97.5% | 28.083 |
| | 90.0% | 10.933 |
| quartile | 75.0% | 4.550 |
| median | 50.0% | 0.232 |
| quartile | 25.0% | -3.971 |
| | 10.0% | -9.537 |
| | 2.5% | -19.839 |
| | 0.5% | -36.939 |
| minimum | 0.0% | -58.652 |

| Moments | |
|---|---|
| Mean | 0.844 |
| Std Dev | 11.049 |
| Std Error Mean | 0.177 |
| Upper 95% Mean | 1.191 |
| Lower 95% Mean | 0.498 |
| N | 3912.000 |
| Sum Weights | 3912.000 |

**Figure A.2- 41 Histogram and Quantile for Longitudinal Error and Look Ahead Time 1800 for Samples at Altitudes Above 18,000 Feet**




| | Quantiles | |
|---|---|---|
| maximum | 100.0% | 29003 |
| | 99.5% | 12994 |
| | 97.5% | 5983 |
| | 90.0% | 2638 |
| quartile | 75.0% | 0 |
| median | 50.0% | 0 |
| quartile | 25.0% | -6 |
| | 10.0% | -3000 |
| | 2.5% | -8085 |
| | 0.5% | -12354 |
| minimum | 0.0% | -17851 |

| Moments | |
|---|---|
| Mean | -129.068 |
| Std Dev | 3060.423 |
| Std Error Mean | 48.931 |
| Upper 95% Mean | -33.134 |
| Lower 95% Mean | -225.001 |
| N | 3912.000 |
| Sum Weights | 3912.000 |

**Figure A.2- 42 Histogram and Quantile for Vertical Error and Look Ahead Time 1800 for Samples at Altitudes Above 18,000 Feet**

## *A.2.2 Flight Type Per Look Ahead Time*

A.2.2.1 Summary Tables

| LOOKAHEAD TIME | | | 0 Seconds | |
|---|---|---|---|---|
| Flight type | OVR | ARR | DEP | INR |
| Sample Quantity | 9811 | 9698 | 9424 | 3626 |
| Avg. Horz. Error | 0.24 | 0.31 | 0.25 | 0.33 |
| Stddev. Horz. Error | 0.91 | 0.81 | 0.61 | 1.23 |
| Max. Horz. Error | 48.02 | 19.85 | 21.86 | 33.7 |
| Min. Horz. Error | 0 | 0 | 0 | 0 |
| Avg. Lat. Error | 0 | 0 | -0.01 | 0.02 |
| Stddev. Lat. Error | 0.34 | 0.52 | 0.39 | 0.65 |
| Max. Lat. Error | 22.88 | 18.66 | 10.75 | 13.61 |
| Min. Lat. Error | -3.72 | -15.57 | -11.26 | -5.34 |
| Avg. Abs. Lat. Error | 0.09 | 0.16 | 0.11 | 0.17 |
| Stddev. Abs. Lat. Error | 0.33 | 0.49 | 0.37 | 0.63 |
| Max. Abs. Lat. Error | 22.88 | 18.66 | 11.26 | 13.61 |
| Min. Abs. Lat. Error | 0 | 0 | 0 | 0 |
| Avg. Long. Error | -0.06 | -0.05 | -0.03 | -0.08 |
| Stddev. Long. Error | 0.87 | 0.69 | 0.53 | 1.1 |
| Max. Long. Error | 47.54 | 14.47 | 11.54 | 16.44 |
| Min. Long. Error | -23.09 | -13.58 | -21.17 | -31.16 |
| Avg. Abs. Long. Error | 0.2 | 0.22 | 0.19 | 0.25 |
| Stddev. Abs. Long. Error | 0.85 | 0.66 | 0.49 | 1.07 |
| Max. Abs. Long. Error | 47.54 | 14.47 | 21.17 | 31.16 |
| Min. Abs. Long. Error | 0 | 0 | 0 | 0 |
| Avg. Vert. Error | -26.65 | -136.85 | -86.47 | -223.64 |
| Stddev. Vert. Error | 628.2 | 767.97 | 839.17 | 1035.82 |
| Max. Vert. Error | 17000 | 5200 | 7125 | 18889 |
| Min. Vert. Error | -26348 | -15565.9 | -31466.5 | -13425 |
| Avg. Abs. Vert. Error | 64.75 | 187.89 | 147.88 | 319.91 |
| Stddev. Abs. Vert. Error | 625.42 | 757.1 | 830.55 | 1010.24 |
| Max. Abs. Vert. Error | 26348 | 15565.91 | 31466.46 | 18889 |
| Min. Abs. Vert. Error | 0 | 0 | 0 | 0 |
| Avg. Slant Range Error | 0.24 | 0.32 | 0.26 | 0.35 |
| Stddev. Slant Range Error | 0.91 | 0.82 | 0.62 | 1.24 |
| Max. Slant Range Error | 48.03 | 19.91 | 21.87 | 33.78 |
| Min. Slant Range Error | 0 | 0 | 0 | 0 |

**Figure A.2- 43 Descriptive Statistics for Flight Types at Look Ahead Time of 0 and Samples at All Altitudes**

| LOOKAHEAD TIME | | 300 Seconds | | |
|---|---|---|---|---|
| Flight type | OVR | ARR | DEP | INR |
| Sample Quantity | 8358 | 8055 | 7739 | 2971 |
| Avg. Horz. Error | 1.85 | 3.03 | 2.89 | 3.14 |
| Stddev. Horz. Error | 2.61 | 3.34 | 3.19 | 3.82 |
| Max. Horz. Error | 46.09 | 55.05 | 33.37 | 88.45 |
| Min. Horz. Error | 0 | 0.01 | 0.01 | 0.03 |
| Avg. Lat. Error | -0.06 | -0.06 | 0.19 | 0.08 |
| Stddev. Lat. Error | 2.49 | 3.72 | 3.58 | 3.32 |
| Max. Lat. Error | 27.04 | 46.61 | 32.28 | 29.48 |
| Min. Lat. Error | -22.88 | -46.12 | -25.39 | -36.48 |
| Avg. Abs. Lat. Error | 1.1 | 2.14 | 1.94 | 1.88 |
| Stddev. Abs. Lat. Error | 2.24 | 3.05 | 3.02 | 2.73 |
| Max. Abs. Lat. Error | 27.04 | 46.61 | 32.28 | 36.48 |
| Min. Abs. Lat. Error | 0 | 0 | 0 | 0 |
| Avg. Long. Error | -0.06 | -0.1 | 0.02 | -0.17 |
| Stddev. Long. Error | 2 | 2.55 | 2.38 | 3.66 |
| Max. Long. Error | 46.01 | 22.74 | 15.07 | 17.54 |
| Min. Long. Error | -27.41 | -29.29 | -22.36 | -87.99 |
| Avg. Abs. Long. Error | 1.11 | 1.6 | 1.59 | 1.94 |
| Stddev. Abs. Long. Error | 1.67 | 1.99 | 1.77 | 3.1 |
| Max. Abs. Long. Error | 46.01 | 29.29 | 22.36 | 87.99 |
| Min. Abs. Long. Error | 0 | 0 | 0 | 0 |
| Avg. Vert. Error | -56.9 | -1018.42 | -362.16 | -955.35 |
| Stddev. Vert. Error | 1148.48 | 2461.8 | 2084.76 | 3104.14 |
| Max. Vert. Error | 17000 | 13350 | 13961 | 27290 |
| Min. Vert. Error | -17800 | -17950 | -24677 | -14639 |
| Avg. Abs. Vert. Error | 309.08 | 1532.73 | 1065.32 | 1896.9 |
| Stddev. Abs. Vert. Error | 1107.57 | 2179.04 | 1828.21 | 2636.14 |
| Max. Abs. Vert. Error | 17800 | 17950 | 24677 | 27290 |
| Min. Abs. Vert. Error | 0 | 0 | 0 | 0 |
| Avg. Slant Range Error | 1.86 | 3.07 | 2.91 | 3.19 |
| Stddev. Slant Range Error | 2.61 | 3.33 | 3.19 | 3.81 |
| Max. Slant Range Error | 46.09 | 55.05 | 33.37 | 88.56 |
| Min. Slant Range Error | 0.01 | 0.01 | 0.01 | 0.03 |

**Figure A.2- 44 Descriptive Statistics for Flight Types at Look Ahead Time of 300 and Samples at All Altitudes**

| LOOKAHEAD TIME | | | 600 Seconds | |
|---|---|---|---|---|
| Flight type | OVR | ARR | DEP | INR |
| Sample Quantity | 6964 | 6410 | 6127 | 2378 |
| Avg. Horz. Error | 3.26 | 4.81 | 5.35 | 5.33 |
| Stddev. Horz. Error | 4.41 | 4.73 | 5.48 | 4.89 |
| Max. Horz. Error | 56.87 | 67.08 | 65.69 | 36.75 |
| Min. Horz. Error | 0.01 | 0.02 | 0.01 | 0.04 |
| Avg. Lat. Error | -0.06 | -0.07 | 0.86 | 0.33 |
| Stddev. Lat. Error | 4.23 | 4.89 | 5.96 | 4.82 |
| Max. Lat. Error | 55.5 | 33.84 | 38.94 | 33.12 |
| Min. Lat. Error | -34.77 | -38.27 | -32.29 | -33.24 |
| Avg. Abs. Lat. Error | 1.81 | 2.93 | 3.28 | 2.78 |
| Stddev. Abs. Lat. Error | 3.82 | 3.92 | 5.04 | 3.95 |
| Max. Abs. Lat. Error | 55.5 | 38.27 | 38.94 | 33.24 |
| Min. Abs. Lat. Error | 0 | 0 | 0 | 0 |
| Avg. Long. Error | 0.02 | 0.23 | 0.46 | 0.82 |
| Stddev. Long. Error | 3.49 | 4.64 | 4.72 | 5.32 |
| Max. Long. Error | 46.83 | 59.63 | 30.58 | 34.91 |
| Min. Long. Error | -28 | -59.4 | -59.56 | -26.29 |
| Avg. Abs. Long. Error | 2.04 | 3.02 | 3.19 | 3.66 |
| Stddev. Abs. Long. Error | 2.83 | 3.53 | 3.51 | 3.95 |
| Max. Abs. Long. Error | 46.83 | 59.63 | 59.56 | 34.91 |
| Min. Abs. Long. Error | 0 | 0 | 0 | 0 |
| Avg. Vert. Error | -106.29 | -1923.41 | -140.57 | -1127.88 |
| Stddev. Vert. Error | 1577.38 | 3217.9 | 2691.21 | 3808.73 |
| Max. Vert. Error | 17000 | 17800 | 23878 | 28990 |
| Min. Vert. Error | -16406.8 | -26868 | -14510 | -14944.7 |
| Avg. Abs. Vert. Error | 476.56 | 2388.78 | 1395.55 | 2406.97 |
| Stddev. Abs. Vert. Error | 1507.41 | 2889.25 | 2305.32 | 3159.6 |
| Max. Abs. Vert. Error | 17000 | 26868 | 23878 | 28990 |
| Min. Abs. Vert. Error | 0 | 0 | 0 | 0 |
| Avg. Slant Range Error | 3.28 | 4.87 | 5.38 | 5.38 |
| Stddev. Slant Range Error | 4.41 | 4.71 | 5.48 | 4.88 |
| Max. Slant Range Error | 56.87 | 67.09 | 65.69 | 36.75 |
| Min. Slant Range Error | 0.01 | 0.03 | 0.01 | 0.04 |

**Figure A.2- 45 Descriptive Statistics for Flight Types at Look Ahead Time of 600 and Samples at All Altitudes**

| LOOKAHEAD TIME | | | 900 Seconds | |
|---|---|---|---|---|
| Flight type | OVR | ARR | DEP | INR |
| Sample Quantity | 5655 | 4791 | 4629 | 1846 |
| Avg. Horz. Error | 4.66 | 6.22 | 7.54 | 7.58 |
| Stddev. Horz. Error | 6.17 | 5.88 | 7.06 | 7.04 |
| Max. Horz. Error | 62.17 | 86.49 | 101.09 | 75.25 |
| Min. Horz. Error | 0.01 | 0.02 | 0.03 | 0.05 |
| Avg. Lat. Error | -0.01 | -0.06 | 1.63 | 0.34 |
| Stddev. Lat. Error | 5.9 | 5.33 | 7.65 | 5.97 |
| Max. Lat. Error | 60.84 | 32.02 | 54.78 | 42.67 |
| Min. Lat. Error | -39.76 | -38.45 | -64.27 | -43.96 |
| Avg. Abs. Lat. Error | 2.49 | 3.23 | 4.45 | 3.4 |
| Stddev. Abs. Lat. Error | 5.35 | 4.25 | 6.44 | 4.92 |
| Max. Abs. Lat. Error | 60.84 | 38.45 | 64.27 | 43.96 |
| Min. Abs. Lat. Error | 0 | 0 | 0 | 0 |
| Avg. Long. Error | 0.15 | 0.69 | 0.65 | 2.01 |
| Stddev. Long. Error | 5 | 6.67 | 6.72 | 8.2 |
| Max. Long. Error | 37.39 | 58.31 | 30.21 | 49.55 |
| Min. Long. Error | -31.86 | -83.04 | -78.02 | -61.99 |
| Avg. Abs. Long. Error | 3 | 4.39 | 4.65 | 5.69 |
| Stddev. Abs. Long. Error | 4 | 5.07 | 4.88 | 6.24 |
| Max. Abs. Long. Error | 37.39 | 83.04 | 78.02 | 61.99 |
| Min. Abs. Long. Error | 0 | 0 | 0 | 0 |
| Avg. Vert. Error | -154.69 | -2586.96 | 56.28 | -1322.46 |
| Stddev. Vert. Error | 1947.04 | 3795.44 | 3083.09 | 4361.4 |
| Max. Vert. Error | 17000 | 17747 | 29003 | 28990 |
| Min. Vert. Error | -20550 | -32426 | -17600 | -14560.4 |
| Avg. Abs. Vert. Error | 613.01 | 3059.18 | 1499.78 | 2796.43 |
| Stddev. Abs. Vert. Error | 1854.47 | 3426.17 | 2694.21 | 3598.25 |
| Max. Abs. Vert. Error | 20550 | 32426 | 29003 | 28990 |
| Min. Abs. Vert. Error | 0 | 0 | 0 | 0 |
| Avg. Slant Range Error | 4.68 | 6.3 | 7.57 | 7.63 |
| Stddev. Slant Range Error | 6.17 | 5.85 | 7.05 | 7.03 |
| Max. Slant Range Error | 62.17 | 86.49 | 101.09 | 75.4 |
| Min. Slant Range Error | 0.01 | 0.04 | 0.05 | 0.05 |

**Figure A.2- 46 Descriptive Statistics for Flight Types at Look Ahead Time of 900 and Samples at All Altitudes**

| LOOKAHEAD TIME | | | 1200 Seconds | |
|---|---|---|---|---|
| Flight type | OVR | ARR | DEP | INR |
| Sample Quantity | 4484 | 3585 | 3426 | 1411 |
| Avg. Horz. Error | 6.09 | 7.58 | 9.57 | 9.72 |
| Stddev. Horz. Error | 7.92 | 7.04 | 8.45 | 9.15 |
| Max. Horz. Error | 78.4 | 63.92 | 103.04 | 86.73 |
| Min. Horz. Error | 0.03 | 0.02 | 0.01 | 0.09 |
| Avg. Lat. Error | -0.02 | 0.02 | 2.18 | -0.15 |
| Stddev. Lat. Error | 7.37 | 5.92 | 8.91 | 6.78 |
| Max. Lat. Error | 76.1 | 36.69 | 53.39 | 41.78 |
| Min. Lat. Error | -55.56 | -38.88 | -49.48 | -50.89 |
| Avg. Abs. Lat. Error | 3.11 | 3.53 | 5.4 | 3.88 |
| Stddev. Abs. Lat. Error | 6.68 | 4.76 | 7.41 | 5.56 |
| Max. Abs. Lat. Error | 76.1 | 38.88 | 53.39 | 50.89 |
| Min. Abs. Lat. Error | 0 | 0 | 0 | 0 |
| Avg. Long. Error | 0.37 | 1.39 | 1.12 | 3.55 |
| Stddev. Long. Error | 6.73 | 8.37 | 8.81 | 10.94 |
| Max. Long. Error | 38.33 | 63.92 | 44.46 | 77.59 |
| Min. Long. Error | -40.8 | -38.96 | -94.35 | -85.87 |
| Avg. Abs. Long. Error | 4.03 | 5.64 | 6.21 | 7.71 |
| Stddev. Abs. Long. Error | 5.4 | 6.34 | 6.35 | 8.53 |
| Max. Abs. Long. Error | 40.8 | 63.92 | 94.35 | 85.87 |
| Min. Abs. Long. Error | 0 | 0 | 0 | 0 |
| Avg. Vert. Error | -209.47 | -2970.29 | 68.13 | -1597.06 |
| Stddev. Vert. Error | 2166.89 | 4031.85 | 3271.64 | 4499.37 |
| Max. Vert. Error | 17000 | 15000 | 29003 | 28990 |
| Min. Vert. Error | -25050 | -28868 | -24801 | -16582.5 |
| Avg. Abs. Vert. Error | 711.38 | 3444.47 | 1542.73 | 3014.31 |
| Stddev. Abs. Vert. Error | 2057.46 | 3635 | 2885.76 | 3701.93 |
| Max. Abs. Vert. Error | 25050 | 28868 | 29003 | 28990 |
| Min. Abs. Vert. Error | 0 | 0 | 0 | 0 |
| Avg. Slant Range Error | 6.1 | 7.66 | 9.6 | 9.77 |
| Stddev. Slant Range Error | 7.92 | 7.01 | 8.44 | 9.13 |
| Max. Slant Range Error | 78.4 | 63.95 | 103.05 | 86.86 |
| Min. Slant Range Error | 0.03 | 0.08 | 0.01 | 0.09 |

**Figure A.2- 47 Descriptive Statistics for Flight Types at Look Ahead Time of 1200 and Samples at All Altitudes**

| LOOKAHEAD TIME | | | 1500 Seconds | |
|---|---|---|---|---|
| Flight type | OVR | ARR | DEP | INR |
| Sample Quantity | 3498 | 2394 | 2355 | 1005 |
| Avg. Horz. Error | 7.49 | 9.09 | 11.3 | 12.36 |
| Stddev. Horz. Error | 9.66 | 8.64 | 9.6 | 11.33 |
| Max. Horz. Error | 87.22 | 74.04 | 92.1 | 94.14 |
| Min. Horz. Error | 0.03 | 0.13 | 0.09 | 0.17 |
| Avg. Lat. Error | -0.07 | 0.13 | 2.19 | -0.91 |
| Stddev. Lat. Error | 8.84 | 6.64 | 9.87 | 7.62 |
| Max. Lat. Error | 85.67 | 30.91 | 67.1 | 42.67 |
| Min. Lat. Error | -65.63 | -44.45 | -55.21 | -58.18 |
| Avg. Abs. Lat. Error | 3.72 | 3.91 | 5.97 | 4.39 |
| Stddev. Abs. Lat. Error | 8.02 | 5.37 | 8.16 | 6.29 |
| Max. Abs. Lat. Error | 85.67 | 44.45 | 67.1 | 58.18 |
| Min. Abs. Lat. Error | 0 | 0 | 0 | 0 |
| Avg. Long. Error | 0.63 | 2.51 | 1.51 | 5.42 |
| Stddev. Long. Error | 8.43 | 10.34 | 10.74 | 13.9 |
| Max. Long. Error | 47.19 | 74.04 | 61.01 | 94.14 |
| Min. Long. Error | -49.89 | -45.02 | -73.71 | -64.82 |
| Avg. Abs. Long. Error | 5.05 | 6.99 | 7.75 | 10.15 |
| Stddev. Abs. Long. Error | 6.77 | 8.02 | 7.58 | 10.92 |
| Max. Abs. Long. Error | 49.89 | 74.04 | 73.71 | 94.14 |
| Min. Abs. Long. Error | 0 | 0 | 0 | 0 |
| Avg. Vert. Error | -298.32 | -3329.51 | 90.46 | -1849.84 |
| Stddev. Vert. Error | 2331.38 | 4341.96 | 3310.21 | 4306.76 |
| Max. Vert. Error | 17000 | 10600 | 29003 | 28990 |
| Min. Vert. Error | -22800 | -27901 | -24904 | -18609 |
| Avg. Abs. Vert. Error | 811.85 | 3809.9 | 1565.11 | 3120.37 |
| Stddev. Abs. Vert. Error | 2205.69 | 3927.02 | 2918.06 | 3496.73 |
| Max. Abs. Vert. Error | 22800 | 27901 | 29003 | 28990 |
| Min. Abs. Vert. Error | 0 | 0 | 0 | 0 |
| Avg. Slant Range Error | 7.51 | 9.17 | 11.32 | 12.42 |
| Stddev. Slant Range Error | 9.66 | 8.6 | 9.59 | 11.3 |
| Max. Slant Range Error | 87.23 | 74.04 | 92.1 | 94.14 |
| Min. Slant Range Error | 0.03 | 0.16 | 0.09 | 0.2 |

**Figure A.2- 48 Descriptive Statistics for Flight Types at Look Ahead Time of 1500 and Samples at All Altitudes**

| LOOKAHEAD TIME | | 1800 Seconds | | |
|---|---|---|---|---|
| Flight type | OVR | ARR | DEP | INR |
| Sample Quantity | 2714 | 1634 | 1567 | 737 |
| Avg. Horz. Error | 8.85 | 11.02 | 12.6 | 14.96 |
| Stddev. Horz. Error | 11.12 | 10.48 | 10.48 | 12.91 |
| Max. Horz. Error | 87.65 | 73.08 | 98.82 | 96.9 |
| Min. Horz. Error | 0.06 | 0.03 | 0.03 | 0.19 |
| Avg. Lat. Error | 0.05 | 0.46 | 2.07 | -1.51 |
| Stddev. Lat. Error | 9.85 | 8.02 | 10.09 | 8.38 |
| Max. Lat. Error | 86.54 | 37.65 | 64.33 | 54.57 |
| Min. Lat. Error | -62.21 | -45.06 | -59.89 | -42.31 |
| Avg. Abs. Lat. Error | 4.26 | 4.65 | 6.05 | 5.09 |
| Stddev. Abs. Lat. Error | 8.89 | 6.55 | 8.34 | 6.82 |
| Max. Abs. Lat. Error | 86.54 | 45.06 | 64.33 | 54.57 |
| Min. Abs. Lat. Error | 0 | 0 | 0 | 0 |
| Avg. Long. Error | 0.95 | 3.68 | 1.35 | 7.4 |
| Stddev. Long. Error | 10.2 | 12.37 | 12.68 | 16.23 |
| Max. Long. Error | 55.83 | 72.38 | 77.47 | 96.86 |
| Min. Long. Error | -58.65 | -50.4 | -78.6 | -77.43 |
| Avg. Abs. Long. Error | 6.08 | 8.56 | 9.16 | 12.53 |
| Stddev. Abs. Long. Error | 8.24 | 9.67 | 8.87 | 12.7 |
| Max. Abs. Long. Error | 58.65 | 72.38 | 78.6 | 96.86 |
| Min. Abs. Long. Error | 0 | 0 | 0 | 0.05 |
| Avg. Vert. Error | -366.26 | -3766.65 | 189.57 | -2143.8 |
| Stddev. Vert. Error | 2399.37 | 4706.02 | 3381.19 | 4302.9 |
| Max. Vert. Error | 17000 | 10300 | 29003 | 24000 |
| Min. Vert. Error | -21800 | -29635 | -19867 | -19613 |
| Avg. Abs. Vert. Error | 888.46 | 4240.85 | 1655 | 3347.76 |
| Stddev. Abs. Vert. Error | 2258.65 | 4283.35 | 2954.25 | 3448.81 |
| Max. Abs. Vert. Error | 21800 | 29635 | 29003 | 24000 |
| Min. Abs. Vert. Error | 0 | 0 | 0 | 0 |
| Avg. Slant Range Error | 8.86 | 11.1 | 12.62 | 15.01 |
| Stddev. Slant Range Error | 11.12 | 10.44 | 10.48 | 12.88 |
| Max. Slant Range Error | 87.65 | 73.08 | 98.82 | 96.91 |
| Min. Slant Range Error | 0.06 | 0.24 | 0.03 | 0.19 |

**Figure A.2- 49 Descriptive Statistics for Flight Types at Look Ahead Time of 1800 and Samples at All Altitudes**

| LOOKAHEAD TIME | | | 0 Seconds | |
|---|---|---|---|---|
| Flight type | OVR | ARR | DEP | INR |
| Sample Quantity | 8622 | 5944 | 5764 | 835 |
| Avg. Horz. Error | 0.23 | 0.25 | 0.26 | 0.36 |
| Stddev. Horz. Error | 0.82 | 0.44 | 0.69 | 1.68 |
| Max. Horz. Error | 48.02 | 17.72 | 21.86 | 33.7 |
| Min. Horz. Error | 0 | 0 | 0 | 0 |
| Avg. Lat. Error | 0 | -0.02 | -0.01 | 0.07 |
| Stddev. Lat. Error | 0.35 | 0.38 | 0.4 | 0.94 |
| Max. Lat. Error | 22.88 | 8.7 | 10.75 | 13.61 |
| Min. Lat. Error | -3.72 | -15.57 | -10.95 | -3.27 |
| Avg. Abs. Lat. Error | 0.09 | 0.13 | 0.11 | 0.19 |
| Stddev. Abs. Lat. Error | 0.34 | 0.36 | 0.38 | 0.93 |
| Max. Abs. Lat. Error | 22.88 | 15.57 | 10.95 | 13.61 |
| Min. Abs. Lat. Error | 0 | 0 | 0 | 0 |
| Avg. Long. Error | -0.04 | -0.06 | -0.02 | -0.17 |
| Stddev. Long. Error | 0.77 | 0.32 | 0.62 | 1.43 |
| Max. Long. Error | 47.54 | 3.56 | 11.54 | 1.81 |
| Min. Long. Error | -23.09 | -8.47 | -21.17 | -31.16 |
| Avg. Abs. Long. Error | 0.19 | 0.17 | 0.2 | 0.27 |
| Stddev. Abs. Long. Error | 0.75 | 0.28 | 0.58 | 1.41 |
| Max. Abs. Long. Error | 47.54 | 8.47 | 21.17 | 31.16 |
| Min. Abs. Long. Error | 0 | 0 | 0 | 0 |
| Avg. Vert. Error | -9.52 | -28.34 | -27.11 | 42.84 |
| Stddev. Vert. Error | 478.37 | 251.04 | 560.78 | 1163.2 |
| Max. Vert. Error | 17000 | 5200 | 7125 | 18889 |
| Min. Vert. Error | -16406.8 | -5451 | -21500 | -11438 |
| Avg. Abs. Vert. Error | 44.64 | 76.9 | 94.69 | 174.86 |
| Stddev. Abs. Vert. Error | 476.38 | 240.64 | 553.39 | 1150.77 |
| Max. Abs. Vert. Error | 17000 | 5451 | 21500 | 18889 |
| Min. Abs. Vert. Error | 0 | 0 | 0 | 0 |
| Avg. Slant Range Error | 0.23 | 0.25 | 0.26 | 0.37 |
| Stddev. Slant Range Error | 0.82 | 0.44 | 0.69 | 1.69 |
| Max. Slant Range Error | 48.03 | 17.73 | 21.87 | 33.78 |
| Min. Slant Range Error | 0 | 0 | 0 | 0 |

**Figure A.2- 50 Descriptive Statistics for Flight Types at Look Ahead Time of 0 and Samples at Altitudes Above 18,000 Feet**

| LOOKAHEAD TIME | | | 300 Seconds | |
|---|---|---|---|---|
| Flight type | OVR | ARR | DEP | INR |
| Sample Quantity | 7337 | 4728 | 5599 | 751 |
| Avg. Horz. Error | 1.84 | 2.89 | 2.89 | 3.68 |
| Stddev. Horz. Error | 2.62 | 3.56 | 3.25 | 5.97 |
| Max. Horz. Error | 46.09 | 55.05 | 33.37 | 88.45 |
| Min. Horz. Error | 0 | 0.01 | 0.01 | 0.03 |
| Avg. Lat. Error | -0.07 | -0.19 | 0.44 | 0.05 |
| Stddev. Lat. Error | 2.56 | 4.05 | 3.68 | 4.79 |
| Max. Lat. Error | 27.04 | 46.61 | 32.28 | 29.48 |
| Min. Lat. Error | -22.88 | -46.12 | -22.33 | -36.48 |
| Avg. Abs. Lat. Error | 1.1 | 2.24 | 1.96 | 2.49 |
| Stddev. Abs. Lat. Error | 2.32 | 3.37 | 3.15 | 4.09 |
| Max. Abs. Lat. Error | 27.04 | 46.61 | 32.28 | 36.48 |
| Min. Abs. Lat. Error | 0 | 0 | 0 | 0 |
| Avg. Long. Error | -0.04 | -0.03 | 0.23 | -0.07 |
| Stddev. Long. Error | 1.91 | 2.13 | 2.27 | 5.13 |
| Max. Long. Error | 46.01 | 17.18 | 15.07 | 16.44 |
| Min. Long. Error | -27.41 | -29.29 | -16.41 | -87.99 |
| Avg. Abs. Long. Error | 1.08 | 1.3 | 1.54 | 1.96 |
| Stddev. Abs. Long. Error | 1.57 | 1.69 | 1.68 | 4.73 |
| Max. Abs. Long. Error | 46.01 | 29.29 | 16.41 | 87.99 |
| Min. Abs. Long. Error | 0 | 0 | 0 | 0 |
| Avg. Vert. Error | 4.41 | -556.71 | -52.77 | 337.43 |
| Stddev. Vert. Error | 982.18 | 2195.66 | 1714.12 | 3794.84 |
| Max. Vert. Error | 17000 | 13350 | 13961 | 27290 |
| Min. Vert. Error | -16146 | -17950 | -18228 | -14133 |
| Avg. Abs. Vert. Error | 241.3 | 1147.69 | 891.7 | 1806.59 |
| Stddev. Abs. Vert. Error | 952.09 | 1952.8 | 1464.83 | 3353.6 |
| Max. Abs. Vert. Error | 17000 | 17950 | 18228 | 27290 |
| Min. Abs. Vert. Error | 0 | 0 | 0 | 0 |
| Avg. Slant Range Error | 1.84 | 2.92 | 2.91 | 3.73 |
| Stddev. Slant Range Error | 2.62 | 3.55 | 3.25 | 5.98 |
| Max. Slant Range Error | 46.09 | 55.05 | 33.37 | 88.56 |
| Min. Slant Range Error | 0.01 | 0.01 | 0.01 | 0.03 |

**Figure A.2- 51 Descriptive Statistics for Flight Types at Look Ahead Time of 300 and Samples at Altitudes Above 18,000 Feet**

| LOOKAHEAD TIME | | | 600 Seconds | |
|---|---|---|---|---|
| Flight type | OVR | ARR | DEP | INR |
| Sample Quantity | 6069 | 3524 | 4601 | 587 |
| Avg. Horz. Error | 3.28 | 4.45 | 5.63 | 6.36 |
| Stddev. Horz. Error | 4.53 | 4.83 | 5.62 | 6.42 |
| Max. Horz. Error | 56.87 | 67.08 | 44.23 | 36.75 |
| Min. Horz. Error | 0.01 | 0.02 | 0.01 | 0.1 |
| Avg. Lat. Error | -0.09 | -0.23 | 1.31 | 0.36 |
| Stddev. Lat. Error | 4.39 | 5.16 | 6.28 | 6.73 |
| Max. Lat. Error | 55.5 | 33.84 | 38.94 | 33.12 |
| Min. Lat. Error | -34.77 | -38.27 | -32.29 | -33.24 |
| Avg. Abs. Lat. Error | 1.84 | 3.05 | 3.5 | 3.8 |
| Stddev. Abs. Lat. Error | 3.99 | 4.16 | 5.37 | 5.57 |
| Max. Abs. Lat. Error | 55.5 | 38.27 | 38.94 | 33.24 |
| Min. Abs. Lat. Error | 0 | 0 | 0 | 0 |
| Avg. Long. Error | 0.02 | 0.13 | 0.72 | 1.34 |
| Stddev. Long. Error | 3.46 | 4.05 | 4.66 | 5.87 |
| Max. Long. Error | 46.83 | 59.63 | 30.58 | 34.91 |
| Min. Long. Error | -28 | -21.22 | -29.72 | -22.22 |
| Avg. Abs. Long. Error | 2.02 | 2.47 | 3.28 | 3.99 |
| Stddev. Abs. Long. Error | 2.82 | 3.21 | 3.39 | 4.5 |
| Max. Abs. Long. Error | 46.83 | 59.63 | 30.58 | 34.91 |
| Min. Abs. Long. Error | 0 | 0 | 0 | 0 |
| Avg. Vert. Error | -1.04 | -1413.52 | 125.61 | 322.53 |
| Stddev. Vert. Error | 1404.76 | 3060.83 | 2690.82 | 5126.08 |
| Max. Vert. Error | 17000 | 17800 | 23878 | 28990 |
| Min. Vert. Error | -16406.8 | -16708 | -14510 | -11000 |
| Avg. Abs. Vert. Error | 391.85 | 1981.42 | 1409.53 | 2698.07 |
| Stddev. Abs. Vert. Error | 1348.99 | 2727.66 | 2295.45 | 4369.08 |
| Max. Abs. Vert. Error | 17000 | 17800 | 23878 | 28990 |
| Min. Abs. Vert. Error | 0 | 0 | 0 | 0 |
| Avg. Slant Range Error | 3.29 | 4.51 | 5.66 | 6.41 |
| Stddev. Slant Range Error | 4.53 | 4.81 | 5.61 | 6.42 |
| Max. Slant Range Error | 56.87 | 67.09 | 44.23 | 36.75 |
| Min. Slant Range Error | 0.01 | 0.03 | 0.01 | 0.13 |

**Figure A.2- 52 Descriptive Statistics for Flight Types at Look Ahead Time of 600 and Samples at Altitudes Above 18,000 Feet**

| LOOKAHEAD TIME | | | 900 Seconds | |
|---|---|---|---|---|
| Flight type | OVR | ARR | DEP | INR |
| Sample Quantity | 4878 | 2454 | 3452 | 414 |
| Avg. Horz. Error | 4.71 | 5.57 | 8.11 | 9.55 |
| Stddev. Horz. Error | 6.37 | 5.69 | 7.02 | 9.42 |
| Max. Horz. Error | 62.17 | 58.36 | 56.6 | 75.25 |
| Min. Horz. Error | 0.01 | 0.06 | 0.04 | 0.11 |
| Avg. Lat. Error | -0.04 | -0.15 | 2.24 | 0.67 |
| Stddev. Lat. Error | 6.15 | 5.57 | 8.15 | 8.75 |
| Max. Lat. Error | 60.84 | 31.18 | 54.78 | 42.67 |
| Min. Lat. Error | -39.76 | -38.45 | -37.58 | -43.96 |
| Avg. Abs. Lat. Error | 2.55 | 3.35 | 4.92 | 4.96 |
| Stddev. Abs. Lat. Error | 5.6 | 4.45 | 6.88 | 7.24 |
| Max. Abs. Lat. Error | 60.84 | 38.45 | 54.78 | 43.96 |
| Min. Abs. Lat. Error | 0 | 0 | 0 | 0.01 |
| Avg. Long. Error | 0.14 | 0.18 | 0.84 | 2.19 |
| Stddev. Long. Error | 5 | 5.69 | 6.54 | 9.91 |
| Max. Long. Error | 37.39 | 58.31 | 30.21 | 49.55 |
| Min. Long. Error | -31.86 | -25.91 | -36.79 | -61.99 |
| Avg. Abs. Long. Error | 2.96 | 3.54 | 4.8 | 6.72 |
| Stddev. Abs. Long. Error | 4.03 | 4.46 | 4.53 | 7.6 |
| Max. Abs. Long. Error | 37.39 | 58.31 | 36.79 | 61.99 |
| Min. Abs. Long. Error | 0 | 0 | 0 | 0 |
| Avg. Vert. Error | -17.72 | -1885.93 | 422.37 | 618.61 |
| Stddev. Vert. Error | 1771.44 | 3465.79 | 3085.12 | 6181.16 |
| Max. Vert. Error | 17000 | 17747 | 29003 | 28990 |
| Min. Vert. Error | -20550 | -19945.7 | -14955.2 | -14133 |
| Avg. Abs. Vert. Error | 517.43 | 2473.02 | 1501.08 | 3263.83 |
| Stddev. Abs. Vert. Error | 1694.26 | 3074.35 | 2728.1 | 5283.17 |
| Max. Abs. Vert. Error | 20550 | 19945.74 | 29003 | 28990 |
| Min. Abs. Vert. Error | 0 | 0 | 0 | 0 |
| Avg. Slant Range Error | 4.72 | 5.64 | 8.14 | 9.61 |
| Stddev. Slant Range Error | 6.37 | 5.66 | 7.01 | 9.42 |
| Max. Slant Range Error | 62.17 | 58.36 | 56.6 | 75.4 |
| Min. Slant Range Error | 0.01 | 0.11 | 0.05 | 0.23 |

**Figure A.2- 53 Descriptive Statistics for Flight Types at Look Ahead Time of 900 and Samples at Altitudes Above 18,000 Feet**

| LOOKAHEAD TIME | | 1200 Seconds | | |
|---|---|---|---|---|
| Flight type | OVR | ARR | DEP | INR |
| Sample Quantity | 3806 | 1595 | 2511 | 262 |
| Avg. Horz. Error | 6.2 | 6.48 | 10.45 | 13.44 |
| Stddev. Horz. Error | 8.27 | 6.48 | 8.24 | 13.19 |
| Max. Horz. Error | 78.4 | 63.92 | 56.61 | 86.73 |
| Min. Horz. Error | 0.03 | 0.02 | 0.01 | 0.39 |
| Avg. Lat. Error | -0.05 | -0.05 | 2.94 | -0.15 |
| Stddev. Lat. Error | 7.76 | 5.95 | 9.55 | 10.05 |
| Max. Lat. Error | 76.1 | 26.35 | 53.39 | 41.78 |
| Min. Lat. Error | -55.56 | -38.88 | -49.48 | -50.89 |
| Avg. Abs. Lat. Error | 3.23 | 3.59 | 6.14 | 5.66 |
| Stddev. Abs. Lat. Error | 7.06 | 4.74 | 7.88 | 8.3 |
| Max. Abs. Lat. Error | 76.1 | 38.88 | 53.39 | 50.89 |
| Min. Abs. Lat. Error | 0 | 0 | 0 | 0 |
| Avg. Long. Error | 0.32 | 0.19 | 1.31 | 3.72 |
| Stddev. Long. Error | 6.82 | 6.97 | 8.68 | 15.5 |
| Max. Long. Error | 38.33 | 63.92 | 44.46 | 77.59 |
| Min. Long. Error | -40.8 | -30.92 | -35.88 | -85.87 |
| Avg. Abs. Long. Error | 4.02 | 4.39 | 6.48 | 10.61 |
| Stddev. Abs. Long. Error | 5.52 | 5.42 | 5.92 | 11.88 |
| Max. Abs. Long. Error | 40.8 | 63.92 | 44.46 | 85.87 |
| Min. Abs. Long. Error | 0 | 0 | 0 | 0.04 |
| Avg. Vert. Error | -26.6 | -1946.08 | 507.25 | 1082.46 |
| Stddev. Vert. Error | 1904.24 | 3537.6 | 3196.61 | 6391.57 |
| Max. Vert. Error | 17000 | 15000 | 29003 | 28990 |
| Min. Vert. Error | -17851 | -19633 | -16708 | -11108 |
| Avg. Abs. Vert. Error | 588.35 | 2612.74 | 1481.99 | 3343.97 |
| Stddev. Abs. Vert. Error | 1811.25 | 3077.91 | 2877.25 | 5550.08 |
| Max. Abs. Vert. Error | 17851 | 19633 | 29003 | 28990 |
| Min. Abs. Vert. Error | 0 | 0 | 0 | 0 |
| Avg. Slant Range Error | 6.22 | 6.55 | 10.46 | 13.48 |
| Stddev. Slant Range Error | 8.27 | 6.44 | 8.23 | 13.19 |
| Max. Slant Range Error | 78.4 | 63.95 | 56.61 | 86.86 |
| Min. Slant Range Error | 0.03 | 0.09 | 0.01 | 0.49 |

**Figure A.2- 54 Descriptive Statistics for Flight Types at Look Ahead Time of 1200 and Samples at Altitudes Above 18,000 Feet**

| LOOKAHEAD TIME | | 1500 Seconds | | |
|---|---|---|---|---|
| Flight type | OVR | ARR | DEP | INR |
| Sample Quantity | 2917 | 975 | 1649 | 155 |
| Avg. Horz. Error | 7.69 | 7.17 | 12.36 | 14.49 |
| Stddev. Horz. Error | 10.2 | 6.29 | 9.55 | 13.37 |
| Max. Horz. Error | 87.22 | 39.59 | 85.79 | 75.25 |
| Min. Horz. Error | 0.03 | 0.13 | 0.09 | 0.74 |
| Avg. Lat. Error | -0.1 | -0.15 | 3.1 | -2.24 |
| Stddev. Lat. Error | 9.43 | 6.6 | 10.56 | 9.81 |
| Max. Lat. Error | 85.67 | 27.93 | 67.1 | 42.67 |
| Min. Lat. Error | -65.63 | -38.45 | -53.87 | -58.18 |
| Avg. Abs. Lat. Error | 3.92 | 3.96 | 6.88 | 5.47 |
| Stddev. Abs. Lat. Error | 8.57 | 5.28 | 8.59 | 8.44 |
| Max. Abs. Lat. Error | 85.67 | 38.45 | 67.1 | 58.18 |
| Min. Abs. Lat. Error | 0 | 0 | 0 | 0.02 |
| Avg. Long. Error | 0.54 | 0.35 | 1.33 | 3.18 |
| Stddev. Long. Error | 8.6 | 6.88 | 11 | 16.69 |
| Max. Long. Error | 47.19 | 39.59 | 61.01 | 63.91 |
| Min. Long. Error | -49.89 | -26.43 | -53.47 | -61.99 |
| Avg. Abs. Long. Error | 5.04 | 4.83 | 8.14 | 11.85 |
| Stddev. Abs. Long. Error | 6.98 | 4.91 | 7.52 | 12.15 |
| Max. Abs. Long. Error | 49.89 | 39.59 | 61.01 | 63.91 |
| Min. Abs. Long. Error | 0 | 0 | 0 | 0.4 |
| Avg. Vert. Error | -91.11 | -1991.53 | 662.11 | 540.24 |
| Stddev. Vert. Error | 2072.35 | 3683.8 | 3089.13 | 5740.7 |
| Max. Vert. Error | 17000 | 10600 | 29003 | 28990 |
| Min. Vert. Error | -20550 | -19924.8 | -13633 | -12269.3 |
| Avg. Abs. Vert. Error | 674.7 | 2779.56 | 1433.13 | 3219.4 |
| Stddev. Abs. Vert. Error | 1961.52 | 3131.57 | 2815.36 | 4776.77 |
| Max. Abs. Vert. Error | 20550 | 19924.8 | 29003 | 28990 |
| Min. Abs. Vert. Error | 0 | 0 | 0 | 0 |
| Avg. Slant Range Error | 7.7 | 7.23 | 12.37 | 14.53 |
| Stddev. Slant Range Error | 10.19 | 6.26 | 9.54 | 13.37 |
| Max. Slant Range Error | 87.23 | 39.59 | 85.79 | 75.4 |
| Min. Slant Range Error | 0.03 | 0.22 | 0.09 | 0.74 |

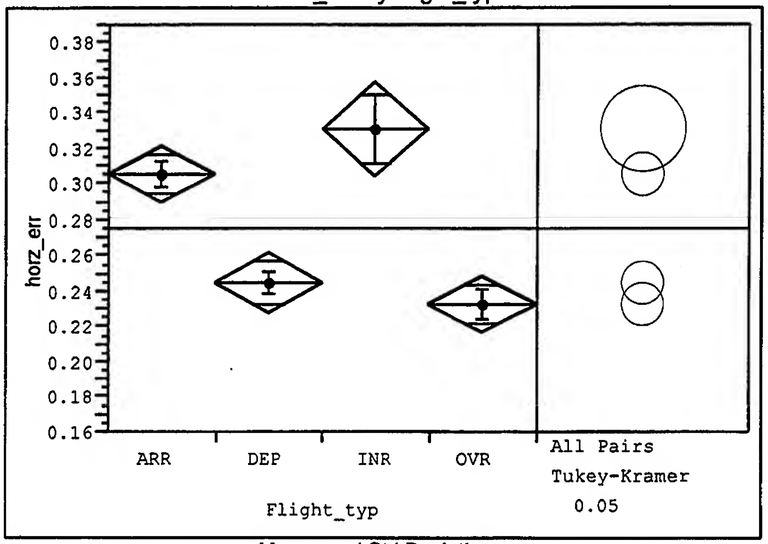
**Figure A.2- 55 Descriptive Statistics for Flight Types at Look Ahead Time of 1500 and Samples All Altitudes Above 18,000 Feet**

| LOOKAHEAD TIME | | 1800 Seconds | | |
|---|---|---|---|---|
| Flight type | OVR | ARR | DEP | INR |
| Sample Quantity | 2217 | 568 | 1051 | 76 |
| Avg. Horz. Error | 9.14 | 8.36 | 13.61 | 15.31 |
| Stddev. Horz. Error | 11.83 | 7.47 | 10.03 | 14.12 |
| Max. Horz. Error | 87.65 | 48.09 | 77.52 | 70.24 |
| Min. Horz. Error | 0.06 | 0.03 | 0.03 | 0.28 |
| Avg. Lat. Error | 0.04 | -0.5 | 3.08 | -3.64 |
| Stddev. Lat. Error | 10.59 | 8.21 | 10.43 | 9.85 |
| Max. Lat. Error | 86.54 | 26.68 | 38.98 | 21.05 |
| Min. Lat. Error | -62.21 | -45.06 | -54.59 | -42.31 |
| Avg. Abs. Lat. Error | 4.55 | 4.86 | 6.85 | 6.07 |
| Stddev. Abs. Lat. Error | 9.57 | 6.63 | 8.44 | 8.55 |
| Max. Abs. Lat. Error | 86.54 | 45.06 | 54.59 | 42.31 |
| Min. Abs. Lat. Error | 0 | 0 | 0 | 0 |
| Avg. Long. Error | 0.86 | 0.83 | 0.88 | -0.09 |
| Stddev. Long. Error | 10.52 | 7.58 | 12.92 | 18.07 |
| Max. Long. Error | 55.83 | 44.94 | 77.47 | 69.78 |
| Min. Long. Error | -58.65 | -26.15 | -38.24 | -38.11 |
| Avg. Abs. Long. Error | 6.11 | 5.44 | 9.57 | 12.14 |
| Stddev. Abs. Long. Error | 8.6 | 5.34 | 8.73 | 13.31 |
| Max. Abs. Long. Error | 58.65 | 44.94 | 77.47 | 69.78 |
| Min. Abs. Long. Error | 0 | 0 | 0 | 0.05 |
| Avg. Vert. Error | -118.67 | -2134.48 | 854.48 | 954.04 |
| Stddev. Vert. Error | 2096.6 | 4030.35 | 3332.79 | 5918.06 |
| Max. Vert. Error | 17000 | 10300 | 29003 | 24000 |
| Min. Vert. Error | -17851 | -16650 | -12600 | -11111 |
| Avg. Abs. Vert. Error | 724.52 | 3095.99 | 1601.06 | 3628.15 |
| Stddev. Abs. Vert. Error | 1970.95 | 3347.49 | 3045.08 | 4754.66 |
| Max. Abs. Vert. Error | 17851 | 16650 | 29003 | 24000 |
| Min. Abs. Vert. Error | 0 | 0 | 0 | 0 |
| Avg. Slant Range Error | 9.15 | 8.42 | 13.63 | 15.34 |
| Stddev. Slant Range Error | 11.83 | 7.44 | 10.02 | 14.12 |
| Max. Slant Range Error | 87.65 | 48.12 | 77.67 | 70.29 |
| Min. Slant Range Error | 0.06 | 0.24 | 0.03 | 0.28 |

**Figure A.2- 56 Descriptive Statistics for Flight Types at Look Ahead Time of 1800 and Samples at Altitudes Above 18,000 Feet**

### A.2.2.2 Statistical Tests

horz_err By Flight_typ




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 9698 | 0.310898 | 0.80951 | 0.00822 |
| DEP | 9424 | 0.252214 | 0.60633 | 0.00625 |
| INR | 3626 | 0.334457 | 1.23489 | 0.02051 |
| OVR | 9811 | 0.240831 | 0.90871 | 0.00917 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | INR | ARR | DEP | OVR |
|---|---|---|---|---|
| INR | 0.000000 | 0.023559 | 0.082243 | 0.093626 |
| ARR | -0.02356 | 0.000000 | 0.058684 | 0.070067 |
| DEP | -0.08224 | -0.05868 | 0.000000 | 0.011383 |
| OVR | -0.09363 | -0.07007 | -0.01138 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q*=2.56916

| Abs(Dif)-LSD | INR | ARR | DEP | OVR |
|---|---|---|---|---|
| INR | -0.05121 | -0.01888 | 0.039634 | 0.051251 |
| ARR | -0.01888 | -0.03131 | 0.027145 | 0.038845 |
| DEP | 0.039634 | 0.027145 | -0.03176 | -0.02007 |
| OVR | 0.051251 | 0.038845 | -0.02007 | -0.03113 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

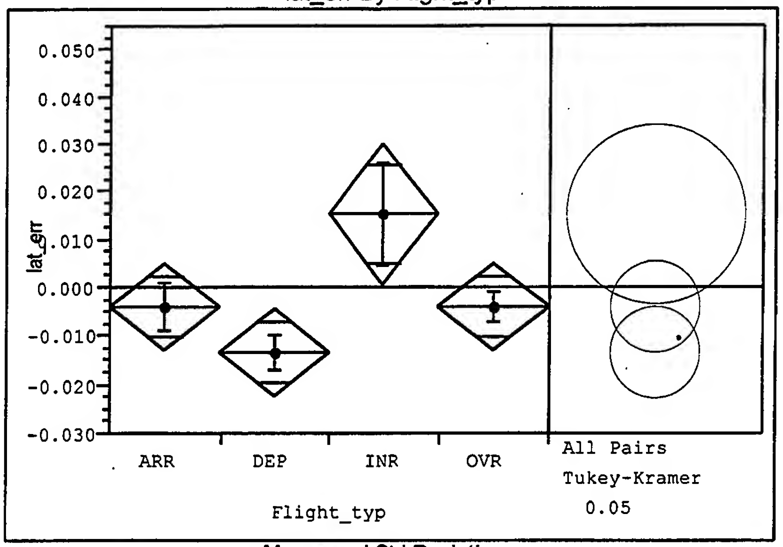
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 9698 | 0.809514 | 0.2831427 | 0.2338476 |
| DEP | 9424 | 0.606328 | 0.2143921 | 0.1806981 |
| INR | 3626 | 1.234889 | 0.3370098 | 0.2656528 |
| OVR | 9811 | 0.908712 | 0.2119356 | 0.1740642 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 3.7896 | 3 | 32555 | 0.0099 |
| Brown-Forsythe | 17.3523 | 3 | 32555 | <.0001 |
| Levene | 32.5325 | 3 | 32555 | <.0001 |
| Bartlett | 1064.1399 | 3 | ? | 0.0000 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 17.6030 | 3 | 12510 | <.0001 |

**Figure A.2- 57 Statistical Tests for Horizontal Error and Flight Type at Look Ahead Time 0 for Samples at All Altitudes**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 9698 | -0.00095 | 0.519224 | 0.00527 |
| DEP | 9424 | -0.01009 | 0.387463 | 0.00399 |
| INR | 3626 | 0.018935 | 0.648047 | 0.01076 |
| OVR | 9811 | 0.004879 | 0.344793 | 0.00348 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | INR | OVR | ARR | DEP |
|---|---|---|---|---|
| INR | 0.000000 | 0.014056 | 0.019886 | 0.029028 |
| OVR | -0.01406 | 0.000000 | 0.005830 | 0.014972 |
| ARR | -0.01989 | -0.00583 | 0.000000 | 0.009142 |
| DEP | -0.02903 | -0.01497 | -0.00914 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q*=2.56916

| Abs(Dif)-LSD | INR | OVR | ARR | DEP |
|---|---|---|---|---|
| INR | -0.02741 | -0.00863 | -0.00283 | 0.006221 |
| OVR | -0.00863 | -0.01666 | -0.01088 | -0.00186 |
| ARR | -0.00283 | -0.01088 | -0.01676 | -0.00774 |
| DEP | 0.006221 | -0.00186 | -0.00774 | -0.017 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

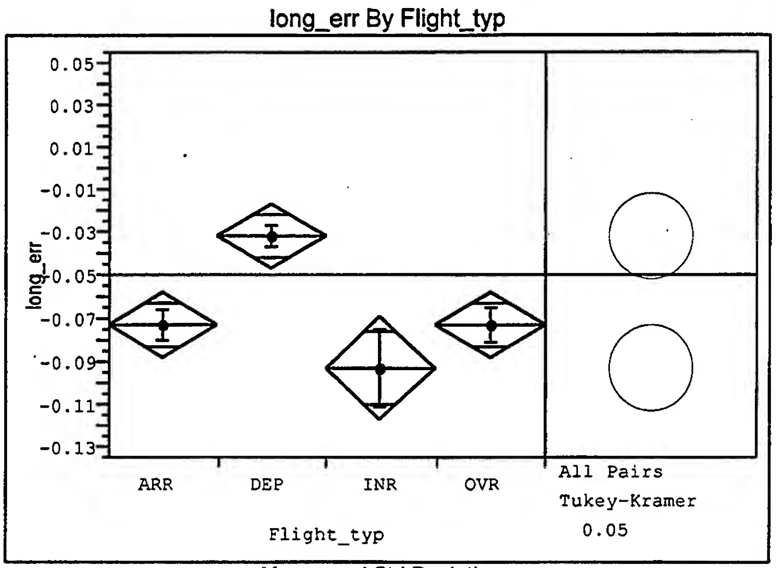
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 9698 | 0.5192241 | 0.1598022 | 0.1598021 |
| DEP | 9424 | 0.3874632 | 0.1150324 | 0.1139145 |
| INR | 3626 | 0.6480467 | 0.1747049 | 0.1703137 |
| OVR | 9811 | 0.3447934 | 0.0888259 | 0.0884648 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 4.4078 | 3 | 32555 | 0.0042 |
| Brown-Forsythe | 58.7598 | 3 | 32555 | <.0001 |
| Levene | 60.5115 | 3 | 32555 | <.0001 |
| Bartlett | 1079.1302 | 3 | ? | 0.0000 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 3.8104 | 3 | 12523 | 0.0096 |

**Figure A.2- 58 Statistical Tests for Lateral Error and Flight Type at Look Ahead Time 0 for Samples at All Altitudes**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 9698 | -0.05228 | 0.69257 | 0.00703 |
| DEP | 9424 | -0.02979 | 0.52928 | 0.00545 |
| INR | 3626 | -0.0791 | 1.10012 | 0.01827 |
| OVR | 9811 | -0.05522 | 0.87282 | 0.00881 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | DEP | ARR | OVR | INR |
|---|---|---|---|---|
| DEP | 0.000000 | 0.022487 | 0.025426 | 0.049301 |
| ARR | -0.02249 | 0.000000 | 0.002939 | 0.026814 |
| OVR | -0.02543 | -0.00294 | 0.000000 | 0.023875 |
| INR | -0.0493 | -0.02681 | -0.02388 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q*=2.56916

| Abs(Dif)-LSD | DEP | ARR | OVR | INR |
|---|---|---|---|---|
| DEP | -0.02871 | -0.00602 | -0.003 | 0.010793 |
| ARR | -0.00602 | -0.0283 | -0.02528 | -0.01154 |
| OVR | -0.003 | -0.02528 | -0.02813 | -0.01442 |
| INR | 0.010793 | -0.01154 | -0.01442 | -0.04628 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 9698 | 0.692568 | 0.2154040 | 0.2153890 |
| DEP | 9424 | 0.529277 | 0.1871705 | 0.1865599 |
| INR | 3626 | 1.100120 | 0.2469661 | 0.2427026 |
| OVR | 9811 | 0.872815 | 0.1980230 | 0.1969770 |

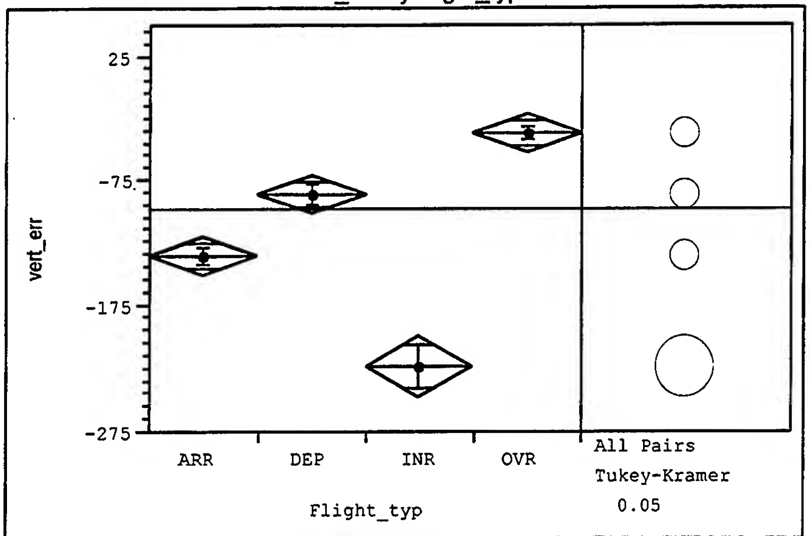
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 3.3723 | 3 | 32555 | 0.0176 |
| Brown-Forsythe | 6.1180 | 3 | 32555 | 0.0004 |
| Levene | 6.6584 | 3 | 32555 | 0.0002 |
| Bartlett | 1273.2348 | 3 | ? | 0.0000 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 4.4776 | 3 | 12473 | 0.0038 |

**Figure A.2- 59 Statistical Tests for Longitudinal Error and Flight Type at Look Ahead Time 0 for Samples at All Altitudes**

vert_err By Flight_typ




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 9698 | -136.853 | 767.97 | 7.798 |
| DEP | 9424 | -86.469 | 839.17 | 8.644 |
| INR | 3626 | -223.639 | 1035.82 | 17.202 |
| OVR | 9811 | -26.653 | 628.20 | 6.342 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | OVR | DEP | ARR | INR |
|---|---|---|---|---|
| OVR | 0.000 | 59.817 | 110.200 | 196.987 |
| DEP | -59.817 | 0.000 | 50.383 | 137.170 |
| ARR | -110.200 | -50.383 | 0.000 | 86.787 |
| INR | -196.987 | -137.170 | -86.787 | 0.000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q*=2.56916

| Abs(Dif)-LSD | OVR | DEP | ARR | INR |
|---|---|---|---|---|
| OVR | -28.834 | 30.688 | 81.282 | 157.738 |
| DEP | 30.688 | -29.420 | 21.171 | 97.704 |
| ARR | 81.282 | 21.171 | -29.002 | 47.476 |
| INR | 157.738 | 97.704 | 47.476 | -47.430 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

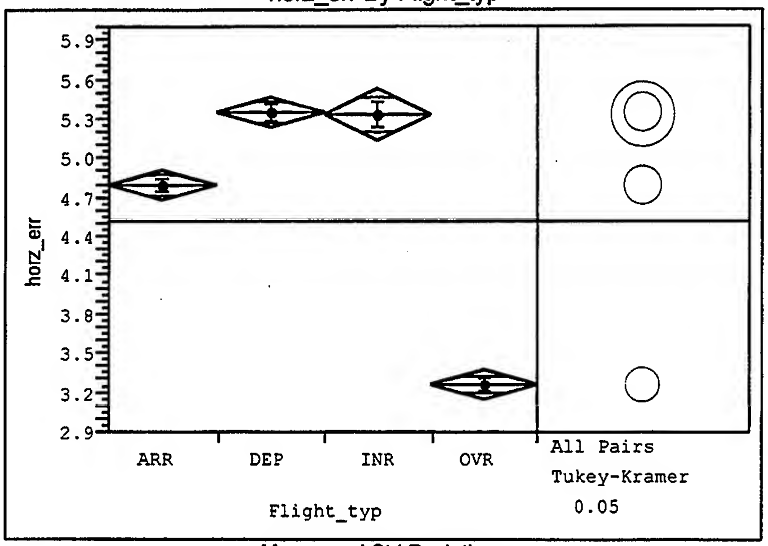
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 9698 | 767.970 | 249.2032 | 187.8927 |
| DEP | 9424 | 839.169 | 185.1839 | 147.8805 |
| INR | 3626 | 1035.819 | 405.3568 | 319.9138 |
| OVR | 9811 | 628.197 | 85.1985 | 64.7526 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 2.6194 | 3 | 32555 | 0.0491 |
| Brown-Forsythe | 104.9176 | 3 | 32555 | <.0001 |
| Levene | 180.2678 | 3 | 32555 | <.0001 |
| Bartlett | 539.1360 | 3 | ? | 0.0000 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 64.5361 | 3 | 12695 | <.0001 |

Figure A.2- 60 Statistical Tests for Vertical Error and Flight Type at Look Ahead Time 0 for Samples at All Altitudes




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 6410 | 4.81263 | 4.72863 | 0.05906 |
| DEP | 6127 | 5.35402 | 5.48387 | 0.07006 |
| INR | 2378 | 5.33299 | 4.88957 | 0.10027 |
| OVR | 6964 | 3.26441 | 4.40919 | 0.05284 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | DEP | INR | ARR | OVR |
|---|---|---|---|---|
| DEP | 0.00000 | 0.02103 | 0.54139 | 2.08961 |
| INR | -0.02103 | 0.00000 | 0.52036 | 2.06858 |
| ARR | -0.54139 | -0.52036 | 0.00000 | 1.54822 |
| OVR | -2.08961 | -2.06858 | -1.54822 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q*=2.56923

| Abs(Dif)-LSD | DEP | INR | ARR | OVR |
|---|---|---|---|---|
| DEP | -0.22626 | -0.28154 | 0.31765 | 1.87026 |
| INR | -0.28154 | -0.36318 | 0.21967 | 1.77114 |
| ARR | 0.31765 | 0.21967 | -0.22121 | 1.33145 |
| OVR | 1.87026 | 1.77114 | 1.33145 | -0.21223 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 6410 | 4.728632 | 3.305763 | 3.089800 |
| DEP | 6127 | 5.483868 | 3.923596 | 3.670080 |
| INR | 2378 | 4.889567 | 3.525267 | 3.368692 |
| OVR | 6964 | 4.409194 | 2.758096 | 2.388764 |

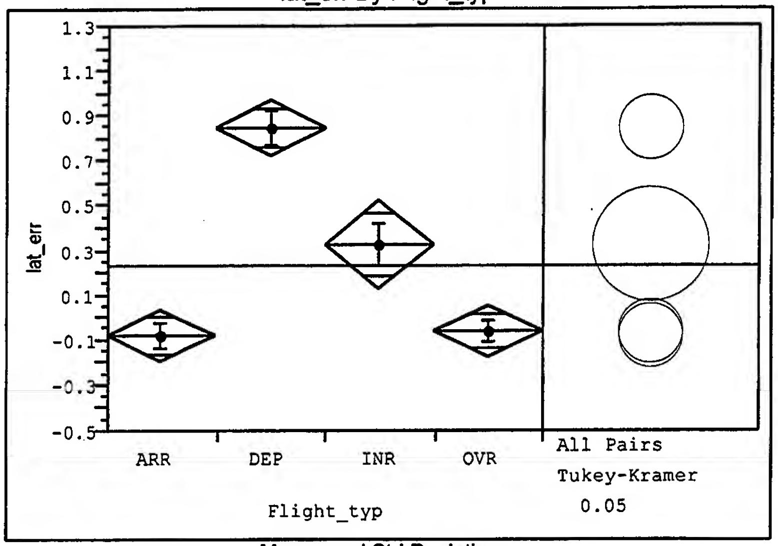
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 14.9169 | 3 | 21875 | <.0001 |
| Brown-Forsythe | 114.0037 | 3 | 21875 | <.0001 |
| Levene | 121.0969 | 3 | 21875 | <.0001 |
| Bartlett | 109.0100 | 3 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 260.8810 | 3 | 8784.1 | <.0001 |

**Figure A.2- 61 Statistical Tests for Horizontal Error and Flight Type at Look Ahead Time 600 for Samples at All Altitudes**

lat_err By Flight_typ




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 6410 | -0.07385 | 4.88907 | 0.06107 |
| DEP | 6127 | 0.855664 | 5.95637 | 0.07610 |
| INR | 2378 | 0.333792 | 4.82253 | 0.09889 |
| OVR | 6964 | -0.05715 | 4.22934 | 0.05068 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | DEP | INR | OVR | ARR |
|---|---|---|---|---|
| DEP | 0.000000 | 0.521872 | 0.912819 | 0.929514 |
| INR | -0.52187 | 0.000000 | 0.390947 | 0.407642 |
| OVR | -0.91282 | -0.39095 | 0.000000 | 0.016695 |
| ARR | -0.92951 | -0.40764 | -0.0167 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q*=2.56923

| Abs(Dif)-LSD | DEP | INR | OVR | ARR |
|---|---|---|---|---|
| DEP | -0.23283 | 0.210513 | 0.687090 | 0.699265 |
| INR | 0.210513 | -0.37373 | 0.084864 | 0.098211 |
| OVR | 0.687090 | 0.084864 | -0.21839 | -0.20637 |
| ARR | 0.699265 | 0.098211 | -0.20637 | -0.22764 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

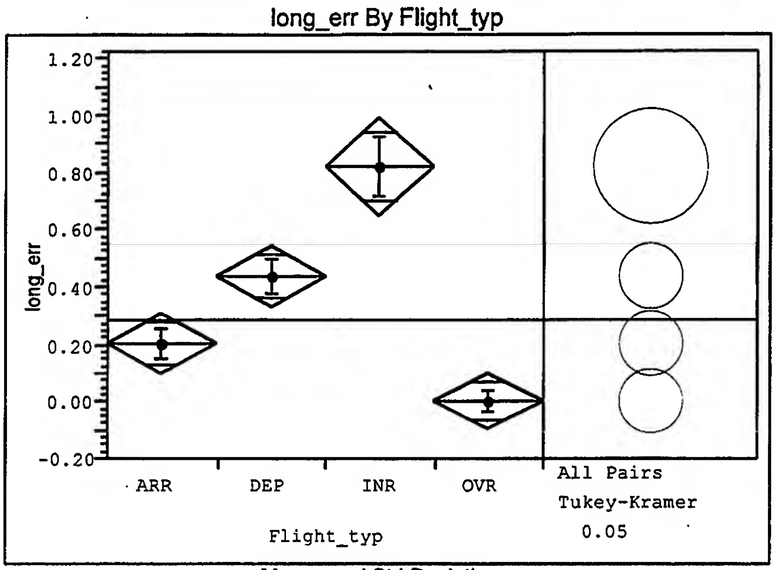
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 6410 | 4.889072 | 2.926194 | 2.925056 |
| DEP | 6127 | 5.956371 | 3.489681 | 3.283112 |
| INR | 2378 | 4.822525 | 2.801543 | 2.776986 |
| OVR | 6964 | 4.229340 | 1.815585 | 1.814337 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 42.1508 | 3 | 21875 | <.0001 |
| Brown-Forsythe | 145.6878 | 3 | 21875 | <.0001 |
| Levene | 184.8489 | 3 | 21875 | <.0001 |
| Bartlett | 261.7352 | 3 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 39.8590 | 3 | 8775.4 | <.0001 |

**Figure A.2- 62 Statistical Tests for Lateral Error and Flight Type at Look Ahead Time 600 for Samples at All Altitudes**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 6410 | 0.233064 | 4.64351 | 0.05800 |
| DEP | 6127 | 0.462771 | 4.72422 | 0.06035 |
| INR | 2378 | 0.821925 | 5.32133 | 0.10912 |
| OVR | 6964 | 0.021720 | 3.49397 | 0.04187 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | INR | DEP | ARR | OVR |
|---|---|---|---|---|
| INR | 0.000000 | 0.359155 | 0.588861 | 0.800205 |
| DEP | -0.35915 | 0.000000 | 0.229706 | 0.441050 |
| ARR | -0.58886 | -0.22971 | 0.000000 | 0.211344 |
| OVR | -0.80021 | -0.44105 | -0.21134 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q*=2.56923

| Abs(Dif)-LSD | INR | DEP | ARR | OVR |
|---|---|---|---|---|
| INR | -0.32928 | 0.084830 | 0.316235 | 0.530529 |
| DEP | 0.084830 | -0.20514 | 0.026844 | 0.242171 |
| ARR | 0.316235 | 0.026844 | -0.20056 | 0.014814 |
| OVR | 0.530529 | 0.242171 | 0.014814 | -0.19242 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 6410 | 4.643507 | 3.004258 | 3.001655 |
| DEP | 6127 | 4.724217 | 3.200885 | 3.188288 |
| INR | 2378 | 5.321330 | 3.635635 | 3.623661 |
| OVR | 6964 | 3.493972 | 2.043733 | 2.043354 |

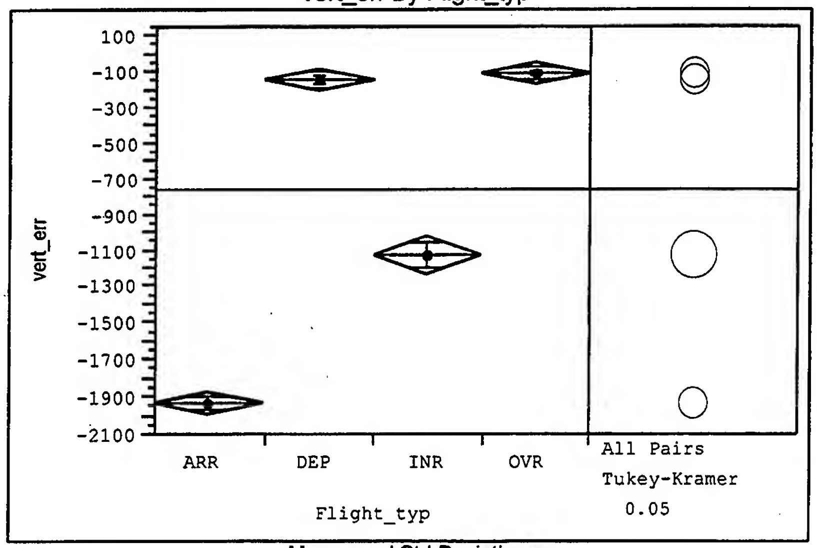
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 39.2139 | 3 | 21875 | <.0001 |
| Brown-Forsythe | 199.5752 | 3 | 21875 | <.0001 |
| Levene | 204.0091 | 3 | 21875 | <.0001 |
| Bartlett | 312.3250 | 3 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 23.0074 | 3 | 8417.5 | <.0001 |

**Figure A.2- 63 Statistical Tests for Longitudinal Error and Flight Type at Look Ahead Time 600 for Samples at All Altitudes**

vert_err By Flight_typ




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 6410 | -1923.41 | 3217.90 | 40.192 |
| DEP | 6127 | -140.57 | 2691.21 | 34.381 |
| INR | 2378 | -1127.88 | 3808.73 | 78.104 |
| OVR | 6964 | -106.29 | 1577.38 | 18.902 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | OVR | DEP | INR | ARR |
|---|---|---|---|---|
| OVR | 0.00 | 34.29 | 1021.59 | 1817.13 |
| DEP | -34.29 | 0.00 | 987.31 | 1782.84 |
| INR | -1021.59 | -987.31 | 0.00 | 795.53 |
| ARR | -1817.13 | -1782.84 | -795.53 | 0.00 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q*=2.56923

| Abs(Dif)-LSD | OVR | DEP | INR | ARR |
|---|---|---|---|---|
| OVR | -118.68 | -88.38 | 855.26 | 1695.90 |
| DEP | -88.38 | -126.53 | 818.10 | 1657.71 |
| INR | 855.26 | 818.10 | -203.10 | 627.37 |
| ARR | 1695.90 | 1657.71 | 627.37 | -123.71 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

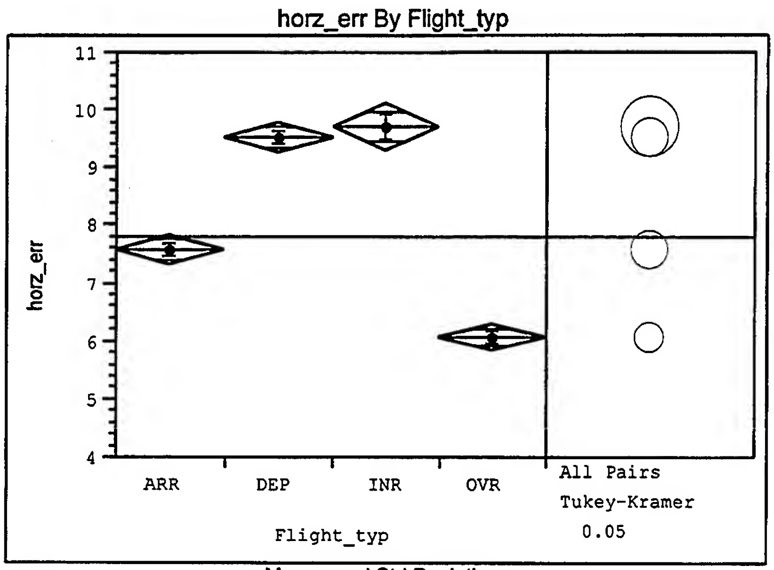
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 6410 | 3217.898 | 2405.257 | 2306.734 |
| DEP | 6127 | 2691.211 | 1453.928 | 1395.545 |
| INR | 2378 | 3808.727 | 2535.934 | 2398.314 |
| OVR | 6964 | 1577.378 | 556.658 | 476.562 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 168.1225 | 3 | 21875 | <.0001 |
| Brown-Forsythe | 886.3388 | 3 | 21875 | 0.0000 |
| Levene | 1068.1096 | 3 | 21875 | 0.0000 |
| Bartlett | 1352.3183 | 3 | ? | 0.0000 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 607.1591 | 3 | 7913.5 | 0.0000 |

**Figure A.2- 64 Statistical Tests for Vertical Error and Flight Type at Look Ahead Time 600 for Samples at All Altitudes**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 3585 | 7.57846 | 7.04364 | 0.11764 |
| DEP | 3426 | 9.57077 | 8.45039 | 0.14437 |
| INR | 1411 | 9.71904 | 9.14956 | 0.24358 |
| OVR | 4484 | 6.08676 | 7.91783 | 0.11824 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | INR | DEP | ARR | OVR |
|---|---|---|---|---|
| INR | 0.00000 | 0.14828 | 2.14058 | 3.63229 |
| DEP | -0.14828 | 0.00000 | 1.99231 | 3.48401 |
| ARR | -2.14058 | -1.99231 | 0.00000 | 1.49171 |
| OVR | -3.63229 | -3.48401 | -1.49171 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q*=2.56937

| Abs(Dif)-LSD | INR | DEP | ARR | OVR |
|---|---|---|---|---|
| INR | -0.77187 | -0.50025 | 1.49627 | 3.00648 |
| DEP | -0.50025 | -0.49535 | 1.50247 | 3.01879 |
| ARR | 1.49627 | 1.50247 | -0.48424 | 1.03237 |
| OVR | 3.00648 | 3.01879 | 1.03237 | -0.43299 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

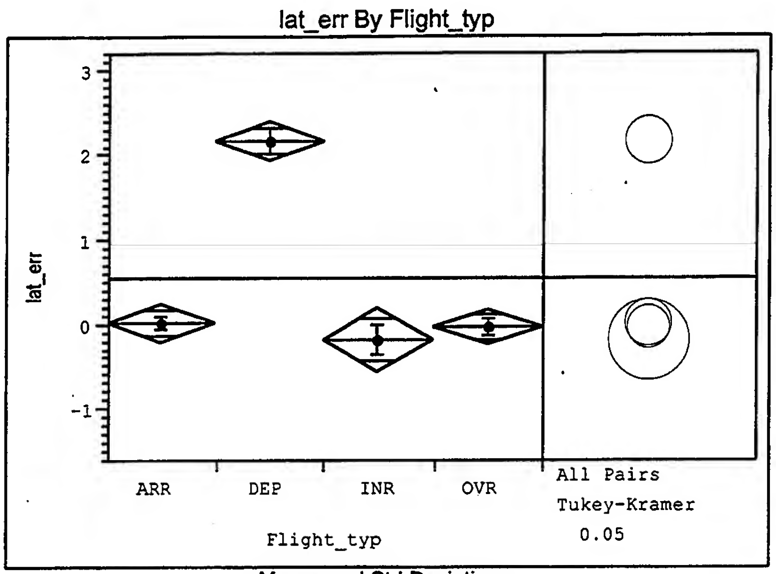
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 3585 | 7.043636 | 5.184324 | 4.855789 |
| DEP | 3426 | 8.450394 | 6.336549 | 6.114365 |
| INR | 1411 | 9.149565 | 6.393235 | 6.153383 |
| OVR | 4484 | 7.917826 | 5.075809 | 4.439521 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 9.1732 | 3 | 12902 | <.0001 |
| Brown-Forsythe | 56.5756 | 3 | 12902 | <.0001 |
| Levene | 47.6911 | 3 | 12902 | <.0001 |
| Bartlett | 61.5680 | 3 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 141.2398 | 3 | 5061.2 | <.0001 |

**Figure A.2- 65 Statistical Tests for Horizontal Error and Flight Type at Look Ahead Time 1200 for Samples at All Altitudes**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 3585 | 0.01866 | 5.92363 | 0.09893 |
| DEP | 3426 | 2.18014 | 8.90710 | 0.15217 |
| INR | 1411 | -0.15311 | 6.78403 | 0.18060 |
| OVR | 4484 | -0.01506 | 7.37213 | 0.11009 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | DEP | ARR | OVR | INR |
|---|---|---|---|---|
| DEP | 0.00000 | 2.16148 | 2.19520 | 2.33325 |
| ARR | -2.16148 | 0.00000 | 0.03372 | 0.17177 |
| OVR | -2.19520 | -0.03372 | 0.00000 | 0.13804 |
| INR | -2.33325 | -0.17177 | -0.13804 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q*=2.56937

| Abs(Dif)-LSD | DEP | ARR | OVR | INR |
|---|---|---|---|---|
| DEP | -0.45923 | 1.70737 | 1.76391 | 1.73202 |
| ARR | 1.70737 | -0.44893 | -0.39211 | -0.42556 |
| OVR | 1.76391 | -0.39211 | -0.40141 | -0.44212 |
| INR | 1.73202 | -0.42556 | -0.44212 | -0.71558 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 3585 | 5.923634 | 3.528745 | 3.527918 |
| DEP | 3426 | 8.907101 | 5.855866 | 5.388564 |
| INR | 1411 | 6.784031 | 3.895724 | 3.882217 |
| OVR | 4484 | 7.372126 | 3.109415 | 3.108946 |

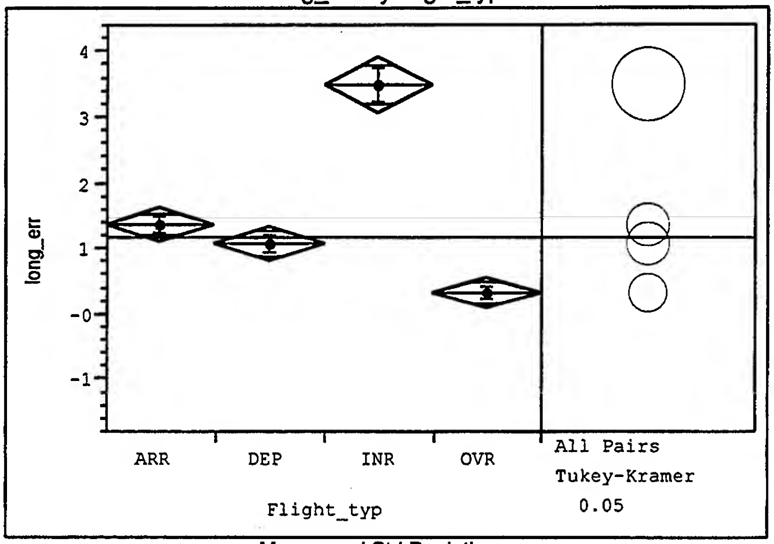
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 27.2043 | 3 | 12902 | <.0001 |
| Brown-Forsythe | 91.5585 | 3 | 12902 | <.0001 |
| Levene | 144.9279 | 3 | 12902 | <.0001 |
| Bartlett | 198.3974 | 3 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 58.1885 | 3 | 5213.7 | <.0001 |

**Figure A.2- 66 Statistical Tests for Lateral Error and Flight Type at Look Ahead Time 1200 for Samples at All Altitudes**

long_err By Flight_typ




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 3585 | 1.38903 | 8.3691 | 0.13978 |
| DEP | 3426 | 1.12294 | 8.8138 | 0.15058 |
| INR | 1411 | 3.54592 | 10.9367 | 0.29116 |
| OVR | 4484 | 0:36605 | 6.7280 | 0.10047 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | INR | ARR | DEP | OVR |
|---|---|---|---|---|
| INR | 0.00000 | 2.15689 | 2.42298 | 3.17987 |
| ARR | -2.15689 | 0.00000 | 0.26609 | 1.02298 |
| DEP | -2.42298 | -0.26609 | 0.00000 | 0.75689 |
| OVR | -3.17987 | -1.02298 | -0.75689 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q*=2.56937

| Abs(Dif)-LSD | INR | ARR | DEP | OVR |
|---|---|---|---|---|
| INR | -0.80283 | 1.48674 | 1.74845 | 2.52897 |
| ARR | 1.48674 | -0.50366 | -0.24338 | 0.54523 |
| DEP | 1.74845 | -0.24338 | -0.51522 | 0.27301 |
| OVR | 2.52897 | 0.54523 | 0.27301 | -0.45035 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

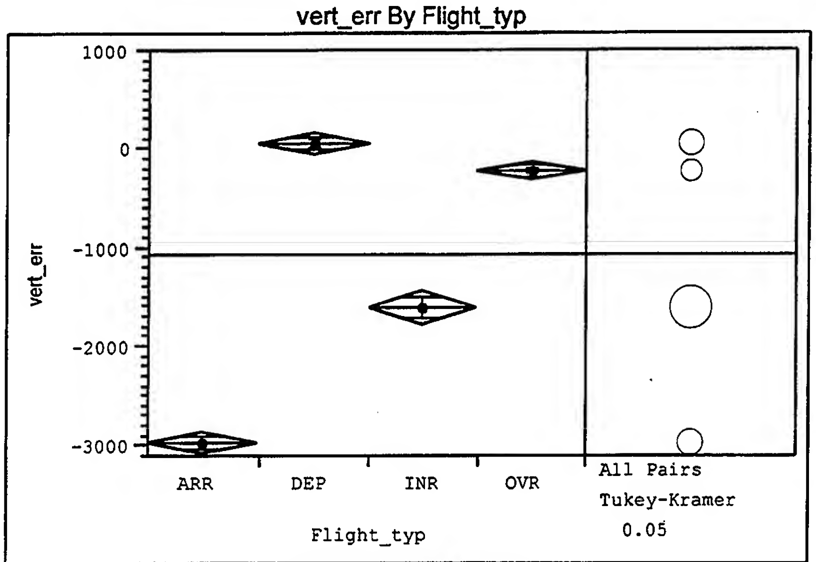
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 3585 | 8.36912 | 5.518321 | 5.514633 |
| DEP | 3426 | 8.81381 | 6.217601 | 6.192209 |
| INR | 1411 | 10.93674 | 7.593686 | 7.471313 |
| OVR | 4484 | 6.72803 | 4.027240 | 4.026134 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 40.8904 | 3 | 12902 | <.0001 |
| Brown-Forsythe | 143.3800 | 3 | 12902 | <.0001 |
| Levene | 153.3512 | 3 | 12902 | <.0001 |
| Bartlett | 210.5479 | 3 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 41.4609 | 3 | 4860.8 | <.0001 |

**Figure A.2- 67 Statistical Tests for Longitudinal Error and Flight Type at Look Ahead Time 1200 for Samples at All Altitudes**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 3585 | -2970.29 | 4031.85 | 67.34 |
| DEP | 3426 | 68.13 | 3271.64 | 55.89 |
| INR | 1411 | -1597.06 | 4499.37 | 119.78 |
| OVR | 4484 | -209.47 | 2166.89 | 32.36 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | DEP | OVR | INR | ARR |
|---|---|---|---|---|
| DEP | 0.00 | 277.60 | 1665.19 | 3038.43 |
| OVR | -277.60 | 0.00 | 1387.59 | 2760.83 |
| INR | -1665.19 | -1387.59 | 0.00 | 1373.23 |
| ARR | -3038.43 | -2760.83 | -1373.23 | 0.00 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q*=2.56937

| Abs(Dif)-LSD | DEP | OVR | INR | ARR |
|---|---|---|---|---|
| DEP | -207.77 | 82.48 | 1393.18 | 2832.98 |
| OVR | 82.48 | -181.61 | 1125.11 | 2568.17 |
| INR | 1393.18 | 1125.11 | -323.75 | 1102.99 |
| ARR | 2832.98 | 2568.17 | 1102.99 | -203.11 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 3585 | 4031.854 | 3023.812 | 2970.805 |
| DEP | 3426 | 3271.645 | 1573.212 | 1542.725 |
| INR | 1411 | 4499.375 | 3116.725 | 2998.359 |
| OVR | 4484 | 2166.889 | 868.074 | 711.378 |

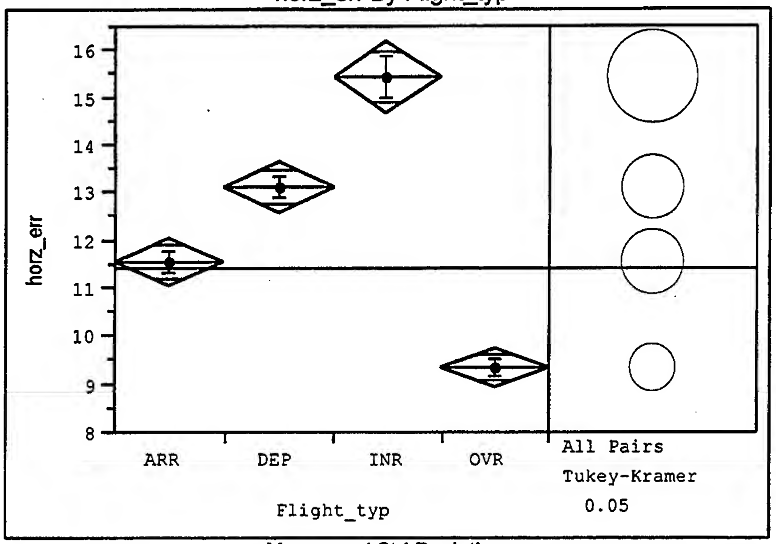
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 87.0695 | 3 | 12902 | <.0001 |
| Brown-Forsythe | 564.8393 | 3 | 12902 | 0.0000 |
| Levene | 586.7886 | 3 | 12902 | 0.0000 |
| Bartlett | 627.8118 | 3 | ? | 0.0000 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 532.1272 | 3 | 4663.8 | <.0001 |

**Figure A.2- 68 Statistical Tests for Vertical Error and Flight Type at Look Ahead Time 1200 for Samples at All Altitudes**

horz_err By Flight_typ




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 1634 | 11.0198 | 10.4753 | 0.25914 |
| DEP | 1567 | 12.6005 | 10.4800 | 0.26474 |
| INR | 737 | 14.9629 | 12.9118 | 0.47561 |
| OVR | 2714 | 8.8507 | 11.1183 | 0.21342 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | INR | DEP | ARR | OVR |
|---|---|---|---|---|
| INR | 0.00000 | 2.36246 | 3.94317 | 6.11220 |
| DEP | -2.36246 | 0.00000 | 1.58071 | 3.74974 |
| ARR | -3.94317 | -1.58071 | 0.00000 | 2.16903 |
| OVR | -6.11220 | -3.74974 | -2.16903 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q*=2.56968

| Abs(Dif)-LSD | INR | DEP | ARR | OVR |
|---|---|---|---|---|
| INR | -1.47693 | 1.09612 | 2.68516 | 4.93456 |
| DEP | 1.09612 | -1.01288 | 0.57826 | 2.85022 |
| ARR | 2.68516 | 0.57826 | -0.99190 | 1.28128 |
| OVR | 4.93456 | 2.85022 | 1.28128 | -0.76964 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

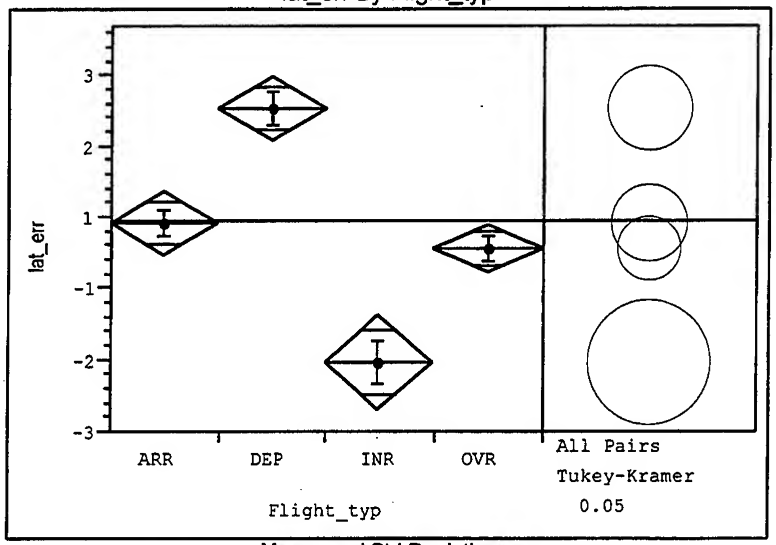
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 1634 | 10.47529 | 7.977267 | 7.289042 |
| DEP | 1567 | 10.47996 | 8.039309 | 7.820326 |
| INR | 737 | 12.91176 | 9.922220 | 9.620093 |
| OVR | 2714 | 11.11833 | 7.250634 | 6.396928 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 4.7179 | 3 | 6648 | 0.0027 |
| Brown-Forsythe | 27.5631 | 3 | 6648 | <.0001 |
| Levene | 23.9272 | 3 | 6648 | <.0001 |
| Bartlett | 19.1123 | 3 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 68.8395 | 3 | 2542.8 | <.0001 |

**Figure A.2- 69 Statistical Tests for Horizontal Error and Flight Type at Look Ahead Time 1800 for Samples at All Altitudes**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 1634 | 0.46028 | 8.0212 | 0.19843 |
| DEP | 1567 | 2.07270 | 10.0917 | 0.25493 |
| INR | 737 | -1.50990 | 8.3800 | 0.30868 |
| OVR | 2714 | 0.05156 | 9.8547 | 0.18916 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | DEP | ARR | OVR | INR |
|---|---|---|---|---|
| DEP | 0.00000 | 1.61242 | 2.02115 | 3.58260 |
| ARR | -1.61242 | 0.00000 | 0.40873 | 1.97018 |
| OVR | -2.02115 | -0.40873 | 0.00000 | 1.56145 |
| INR | -3.58260 | -1.97018 | -1.56145 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q*=2.56968

| Abs(Dif)-LSD | DEP | ARR | OVR | INR |
|---|---|---|---|---|
| DEP | -0.85727 | 0.76398 | 1.25982 | 2.51080 |
| ARR | 0.76398 | -0.83951 | -0.34264 | 0.90543 |
| OVR | 1.25982 | -0.34264 | -0.65140 | 0.56473 |
| INR | 2.51080 | 0.90543 | 0.56473 | -1.25003 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

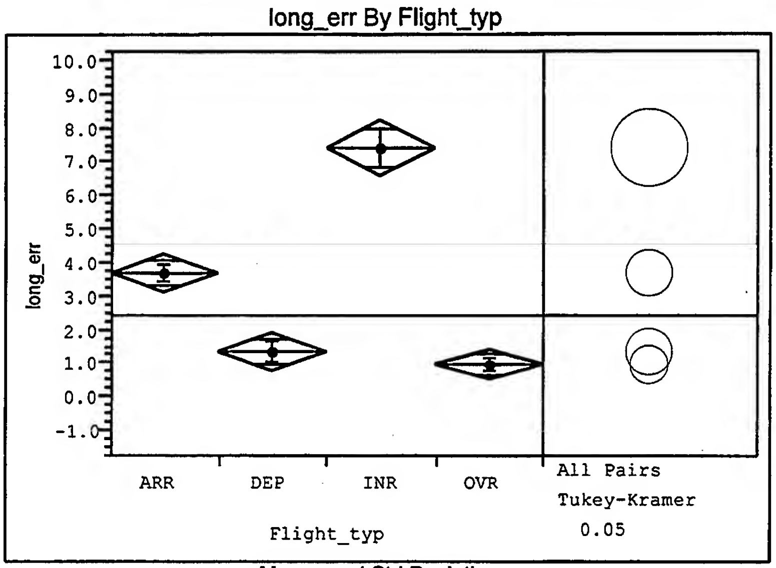
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 1634 | 8.02125 | 4.673304 | 4.643139 |
| DEP | 1567 | 10.09165 | 6.382374 | 6.034568 |
| INR | 737 | 8.38002 | 5.275666 | 5.083819 |
| OVR | 2714 | 9.85469 | 4.269839 | 4.258889 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 4.3364 | 3 | 6648 | 0.0046 |
| Brown-Forsythe | 16.9347 | 3 | 6648 | <.0001 |
| Levene | 25.2209 | 3 | 6648 | <.0001 |
| Bartlett | 40.1958 | 3 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 28.2321 | 3 | 2667.7 | <.0001 |

**Figure A.2- 70 Statistical Tests for Lateral Error and Flight Type at Look Ahead Time 1800 for Samples at All Altitudes**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 1634 | 3.68306 | 12.3740 | 0.30611 |
| DEP | 1567 | 1.35263 | 12.6780 | 0.32027 |
| INR | 737 | 7.40436 | 16.2327 | 0.59794 |
| OVR | 2714 | 0.95296 | 10.1959 | 0.19571 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | INR | ARR | DEP | OVR |
|---|---|---|---|---|
| INR | 0.00000 | 3.72130 | 6.05174 | 6.45140 |
| ARR | -3.72130 | 0.00000 | 2.33044 | 2.73010 |
| DEP | -6.05174 | -2.33044 | 0.00000 | 0.39967 |
| OVR | -6.45140 | -2.73010 | -0.39967 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q*=2.56968

| Abs(Dif)-LSD | INR | ARR | DEP | OVR |
|---|---|---|---|---|
| INR | -1.62338 | 2.33854 | 4.65982 | 5.15699 |
| ARR | 2.33854 | -1.09026 | 1.22859 | 1.75432 |
| DEP | 4.65982 | 1.22859 | -1.11332 | -0.58905 |
| OVR | 5.15699 | 1.75432 | -0.58905 | -0.84596 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 1634 | 12.37400 | 8.40865 | 8.26095 |
| DEP | 1567 | 12.67801 | 9.24024 | 9.15995 |
| INR | 737 | 16.23271 | 12.44291 | 12.07318 |
| OVR | 2714 | 10.19586 | 6.07744 | 6.06200 |

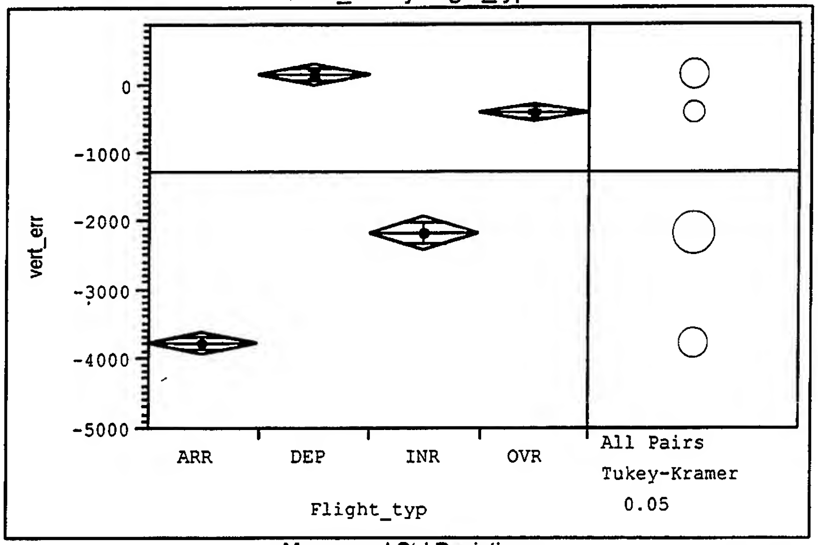
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 33.7000 | 3 | 6648 | <.0001 |
| Brown-Forsythe | 100.4553 | 3 | 6648 | <.0001 |
| Levene | 117.2402 | 3 | 6648 | <.0001 |
| Bartlett | 102.3378 | 3 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 48.1804 | 3 | 2406.4 | <.0001 |

**Figure A.2- 71 Statistical Tests for Longitudinal Error and Flight Type at Look Ahead Time 1800 for Samples at All Altitudes**

vert_err By Flight_typ




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 1634 | -3766.65 | 4706.02 | 116.42 |
| DEP | 1567 | 189.57 | 3381.19 | 85.42 |
| INR | 737 | -2143.80 | 4302.90 | 158.50 |
| OVR | 2714 | -366.26 | 2399.37 | 46.06 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | DEP | OVR | INR | ARR |
|---|---|---|---|---|
| DEP | 0.00 | 555.83 | 2333.37 | 3956.22 |
| OVR | -555.83 | 0.00 | 1777.53 | 3400.39 |
| INR | -2333.37 | -1777.53 | 0.00 | 1622.86 |
| ARR | -3956.22 | -3400.39 | -1622.86 | 0.00 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q*=2.56968

| Abs(Dif)-LSD | DEP | OVR | INR | ARR |
|---|---|---|---|---|
| DEP | -324.99 | 267.21 | 1927.05 | 3634.58 |
| OVR | 267.21 | -246.95 | 1399.68 | 3115.54 |
| INR | 1927.05 | 1399.68 | -473.89 | 1219.21 |
| ARR | 3634.58 | 3115.54 | 1219.21 | -318.26 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 1634 | 4706.017 | 3575.081 | 3503.073 |
| DEP | 1567 | 3381.185 | 1742.939 | 1655.000 |
| INR | 737 | 4302.898 | 3332.569 | 3279.080 |
| OVR | 2714 | 2399.368 | 1148.947 | 888.459 |

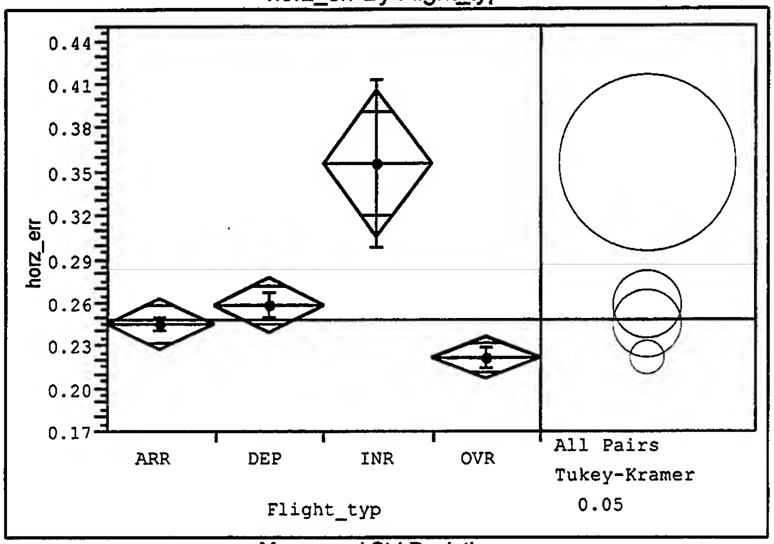
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 70.8944 | 3 | 6648 | <.0001 |
| Brown-Forsythe | 362.5704 | 3 | 6648 | <.0001 |
| Levene | 353.6240 | 3 | 6648 | <.0001 |
| Bartlett | 345.6304 | 3 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 312.4145 | 3 | 2303.9 | <.0001 |

**Figure A.2- 72 Statistical Tests for Vertical Error and Flight Type at Look Ahead Time 1800 for Samples at All Altitudes**

horz_err By Flight_typ




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 5944 | 0.249427 | 0.43739 | 0.00567 |
| DEP | 5764 | 0.259489 | 0.68793 | 0.00906 |
| INR | 835 | 0.363337 | 1.68238 | 0.05822 |
| OVR | 8622 | 0.230576 | 0.81969 | 0.00883 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | INR | DEP | ARR | OVR |
|---|---|---|---|---|
| INR | 0.000000 | 0.103849 | 0.113911 | 0.132762 |
| DEP | -0.10385 | 0.000000 | 0.010062 | 0.028913 |
| ARR | -0.11391 | -0.01006 | 0.000000 | 0.018851 |
| OVR | -0.13276 | -0.02891 | -0.01885 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q*=2.56924

| Abs(Dif)-LSD | INR | DEP | ARR | OVR |
|---|---|---|---|---|
| INR | -0.09476 | 0.032156 | 0.042356 | 0.062589 |
| DEP | 0.032156 | -0.03607 | -0.02573 | -0.00403 |
| ARR | 0.042356 | -0.02573 | -0.03552 | -0.01379 |
| OVR | 0.062589 | -0.00403 | -0.01379 | -0.02949 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 5944 | 0.437388 | 0.1974596 | 0.1709650 |
| DEP | 5764 | 0.687929 | 0.2286337 | 0.1871776 |
| INR | 835 | 1.682376 | 0.3835806 | 0.2871825 |
| OVR | 8622 | 0.819693 | 0.1917282 | 0.1610402 |

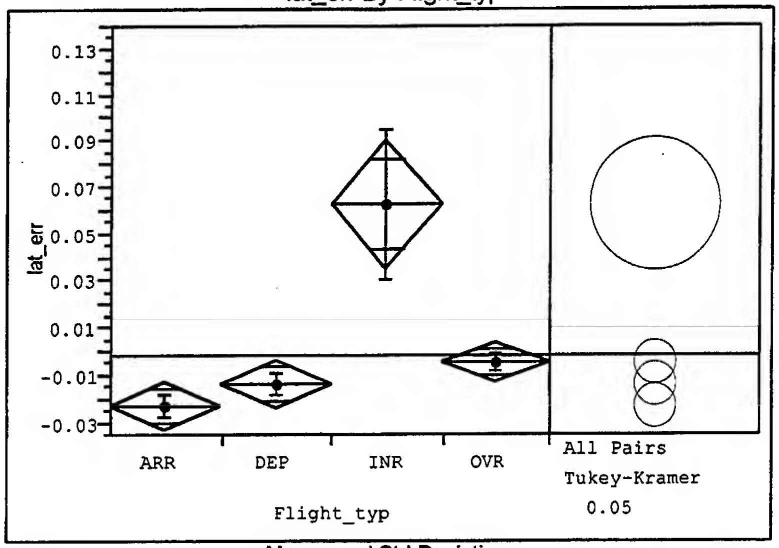
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 4.3325 | 3 | 21161 | 0.0047 |
| Brown-Forsythe | 7.9475 | 3 | 21161 | <.0001 |
| Levene | 19.7693 | 3 | 21161 | <.0001 |
| Bartlett | 1575.5952 | 3 | ? | 0.0000 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 3.1625 | 3 | 3581 | 0.0236 |

**Figure A.2- 73 Statistical Tests for Horizontal Error and Flight Type at Look Ahead Time 0 for Samples at Altitudes Above 18,000 Feet**

lat_err By Flight_typ




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 5944 | -0.01575 | 0.380916 | 0.00494 |
| DEP | 5764 | -0.00519 | 0.396285 | 0.00522 |
| INR | 835 | 0.070869 | 0.942112 | 0.03260 |
| OVR | 8622 | 0.004471 | 0.352300 | 0.00379 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | INR | OVR | DEP | ARR |
|---|---|---|---|---|
| INR | 0.000000 | 0.066398 | 0.076054 | 0.086623 |
| OVR | -0.0664 | 0.000000 | 0.009656 | 0.020225 |
| DEP | -0.07605 | -0.00966 | 0.000000 | 0.010569 |
| ARR | -0.08662 | -0.02022 | -0.01057 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q*=2.56924

| Abs(Dif)-LSD | INR | OVR | DEP | ARR |
|---|---|---|---|---|
| INR | -0.0517 | 0.028110 | 0.036937 | 0.047581 |
| OVR | 0.028110 | -0.01609 | -0.00832 | 0.002415 |
| DEP | 0.036937 | -0.00832 | -0.01968 | -0.00896 |
| ARR | 0.047581 | 0.002415 | -0.00896 | -0.01938 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

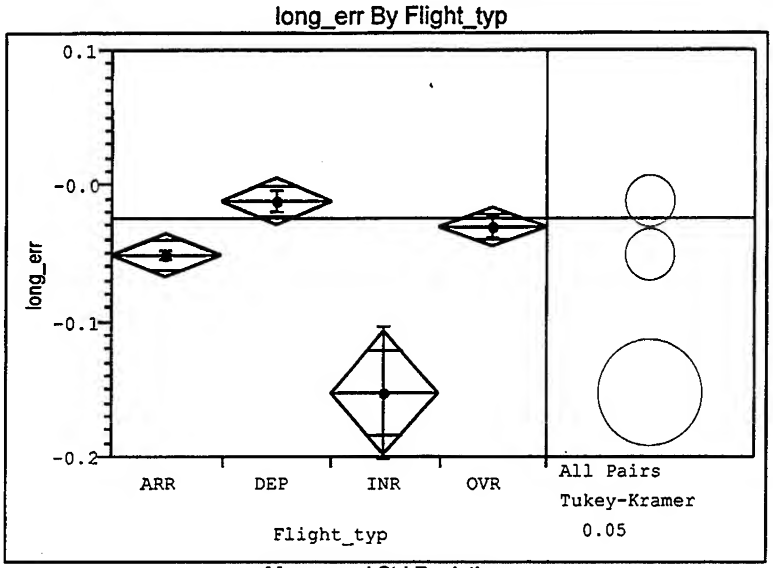
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 5944 | 0.3809155 | 0.1353706 | 0.1336314 |
| DEP | 5764 | 0.3962852 | 0.1079425 | 0.1074727 |
| INR | 835 | 0.9421121 | 0.2163070 | 0.1859559 |
| OVR | 8622 | 0.3523004 | 0.0859581 | 0.0856526 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 6.2767 | 3 | 21161 | 0.0003 |
| Brown-Forsythe | 28.1942 | 3 | 21161 | <.0001 |
| Levene | 39.0256 | 3 | 21161 | <.0001 |
| Bartlett | 871.5923 | 3 | ? | 0.0000 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 5.2806 | 3 | 3564.4 | 0.0012 |

**Figure A.2- 74 Statistical Tests for Lateral Error and Flight Type at Look Ahead Time 0 for Samples at Altitudes Above 18,000 Feet**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 5944 | -0.06046 | 0.32331 | 0.00419 |
| DEP | 5764 | -0.01901 | 0.61900 | 0.00815 |
| INR | 835 | -0.16516 | 1.42921 | 0.04946 |
| OVR | 8622 | -0.03915 | 0.77421 | 0.00834 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | DEP | OVR | ARR | INR |
|---|---|---|---|---|
| DEP | 0.000000 | 0.020141 | 0.041445 | 0.146146 |
| OVR | -0.02014 | 0.000000 | 0.021304 | 0.126005 |
| ARR | -0.04145 | -0.0213 | 0.000000 | 0.104701 |
| INR | -0.14615 | -0.12601 | -0.1047 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q*=2.56924

| Abs(Dif)-LSD | DEP | OVR | ARR | INR |
|---|---|---|---|---|
| DEP | -0.0324 | -0.00945 | 0.009289 | 0.081735 |
| OVR | -0.00945 | -0.02649 | -0.00802 | 0.062959 |
| ARR | 0.009289 | -0.00802 | -0.03191 | 0.040413 |
| INR | 0.081735 | 0.062959 | 0.040413 | -0.08513 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

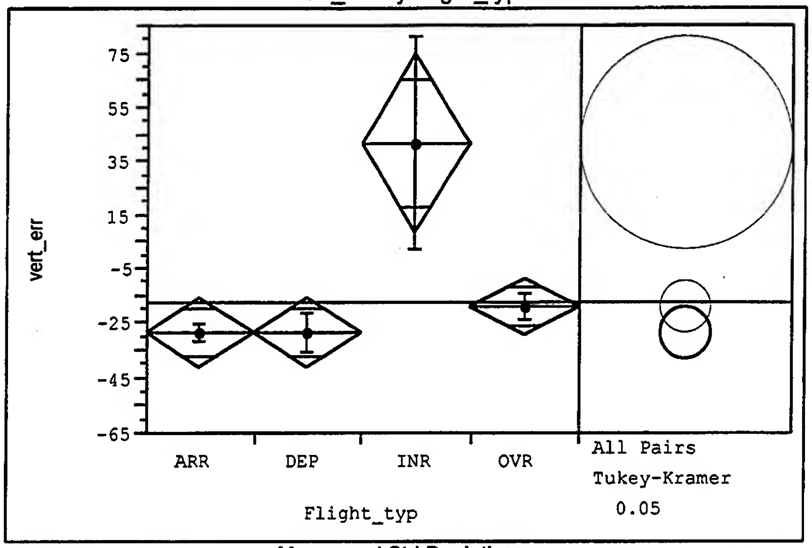
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 5944 | 0.323314 | 0.1660477 | 0.1660012 |
| DEP | 5764 | 0.619000 | 0.2004258 | 0.1987010 |
| INR | 835 | 1.429214 | 0.2944851 | 0.2584907 |
| OVR | 8622 | 0.774209 | 0.1874689 | 0.1874689 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 3.0122 | 3 | 21161 | 0.0288 |
| Brown-Forsythe | 6.0415 | 3 | 21161 | 0.0004 |
| Levene | 10.4225 | 3 | 21161 | <.0001 |
| Bartlett | 2086.4954 | 3 | ? | 0.0000 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 9.2540 | 3 | 3553.9 | <.0001 |

**Figure A.2- 75 Statistical Tests for Longitudinal Error and Flight Type at Look Ahead Time 0 for Samples at Altitudes Above 18,000 Feet**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 5944 | -28.3424 | 251.04 | 3.256 |
| DEP | 5764 | -27.1060 | 560:78 | 7.386 |
| INR | 835 | 42.8403 | 1163.20 | 40.254 |
| OVR | 8622 | -9.5214 | 478.37 | 5.152 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | INR | OVR | DEP | ARR |
|---|---|---|---|---|
| INR | 0.0000 | 52.3618 | 69.9463 | 71.1827 |
| OVR | -52.3618 | 0.0000 | 17.5846 | 18.8210 |
| DEP | -69.9463 | -17.5846 | 0.0000 | 1.2364 |
| ARR | -71.1827 | -18.8210 | -1.2364 | 0.0000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q*=2.56924

| Abs(Dif)-LSD | INR | OVR | DEP | ARR |
|---|---|---|---|---|
| INR | -62.8573 | 5.8124 | 22.3889 | 23.7165 |
| OVR | 5.8124 | -19.5612 | -4.2673 | -2.8317 |
| DEP | 22.3889 | -4.2673 | -23.9242 | -22.5060 |
| ARR | 23.7165 | -2.8317 | -22.5060 | -23.5592 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 5944 | 251.036 | 91.8604 | 76.8985 |
| DEP | 5764 | 560.777 | 109.4045 | 94.6887 |
| INR | 835 | 1163.204 | 202.7138 | 174.8613 |
| OVR | 8622 | 478.370 | 52.4152 | 44.6426 |

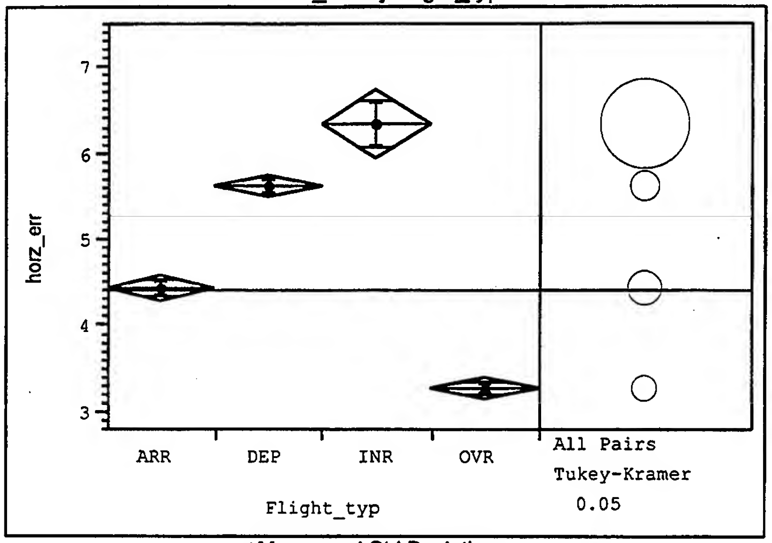
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 9.5397 | 3 | 21161 | <.0001 |
| Brown-Forsythe | 25.0949 | 3 | 21161 | <.0001 |
| Levene | 33.7265 | 3 | 21161 | <.0001 |
| Bartlett | 2070.5746 | 3 | ? | 0.0000 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 4.1701 | 3 | 3540.6 | 0.0059 |

**Figure A.2- 76 Statistical Tests for Vertical Error and Flight Type at Look Ahead Time 0 for Samples at Altitudes Above 18,000 Feet**

horz_err By Flight_typ




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 3524 | 4.44700 | 4.82992 | 0.08136 |
| DEP | 4601 | 5.63019 | 5.62203 | 0.08288 |
| INR | 587 | 6.35718 | 6.42001 | 0.26498 |
| OVR | 6069 | 3.28254 | 4.53168 | 0.05817 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | INR | DEP | ARR | OVR |
|---|---|---|---|---|
| INR | 0.00000 | 0.72699 | 1.91018 | 3.07464 |
| DEP | -0.72699 | 0.00000 | 1.18319 | 2.34765 |
| ARR | -1.91018 | -1.18319 | 0.00000 | 1.16446 |
| OVR | -3.07464 | -2.34765 | -1.16446 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q*=2.56932

| Abs(Dif)-LSD | INR | DEP | ARR | OVR |
|---|---|---|---|---|
| INR | -0.75686 | 0.15870 | 1.33214 | 2.51418 |
| DEP | 0.15870 | -0.27034 | 0.89293 | 2.09419 |
| ARR | 1.33214 | 0.89293 | -0.30890 | 0.88985 |
| OVR | 2.51418 | 2.09419 | 0.88985 | -0.23538 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 3524 | 4.829923 | 3.172503 | 2.900904 |
| DEP | 4601 | 5.622026 | 4.056605 | 3.814293 |
| INR | 587 | 6.420010 | 4.724777 | 4.247451 |
| OVR | 6069 | 4.531681 | 2.816014 | 2.423076 |

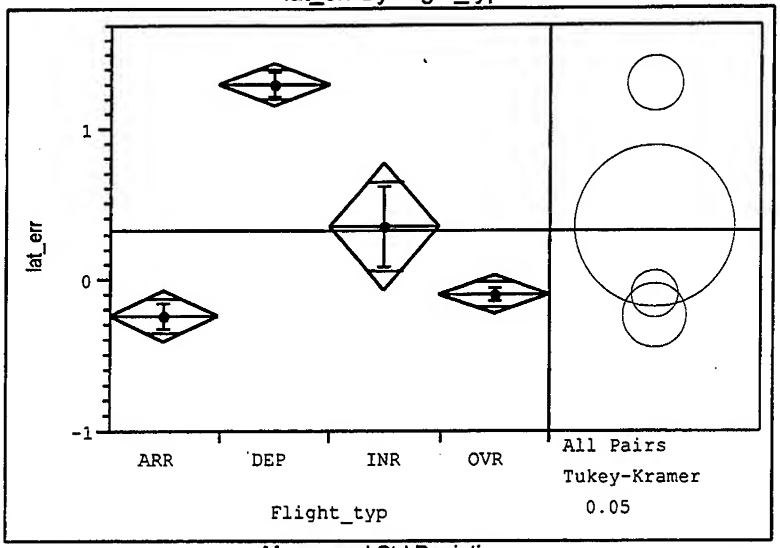
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 16.4402 | 3 | 14777 | <.0001 |
| Brown-Forsythe | 108.2161 | 3 | 14777 | <.0001 |
| Levene | 126.7033 | 3 | 14777 | <.0001 |
| Bartlett | 113.2546 | 3 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 207.2099 | 3 | 2556 | <.0001 |

**Figure A.2- 77 Statistical Tests for Horizontal Error and Flight Type at Look Ahead Time 600 for Samples at Altitudes Above 18,000 Feet**

lat_err By Flight_typ




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 3524 | -0.23310 | 5.15791 | 0.08689 |
| DEP | 4601 | 1.30717 | 6.27613 | 0.09253 |
| INR | 587 | 0.35759 | 6.73425 | 0.27795 |
| OVR | 6069 | -0.09036 | 4.39379 | 0.05640 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | DEP | INR | OVR | ARR |
|---|---|---|---|---|
| DEP | 0.00000 | 0.94957 | 1.39753 | 1.54027 |
| INR | -0.94957 | 0.00000 | 0.44795 | 0.59069 |
| OVR | -1.39753 | -0.44795 | 0.00000 | 0.14274 |
| ARR | -1.54027 | -0.59069 | -0.14274 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q*=2.56932

| Abs(Dif)-LSD | DEP | INR | OVR | ARR |
|---|---|---|---|---|
| DEP | -0.28512 | 0.35020 | 1.13020 | 1.23413 |
| INR | 0.35020 | -0.79825 | -0.14317 | -0.01896 |
| OVR | 1.13020 | -0.14317 | -0.24826 | -0.14689 |
| ARR | 1.23413 | -0.01896 | -0.14689 | -0.32579 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

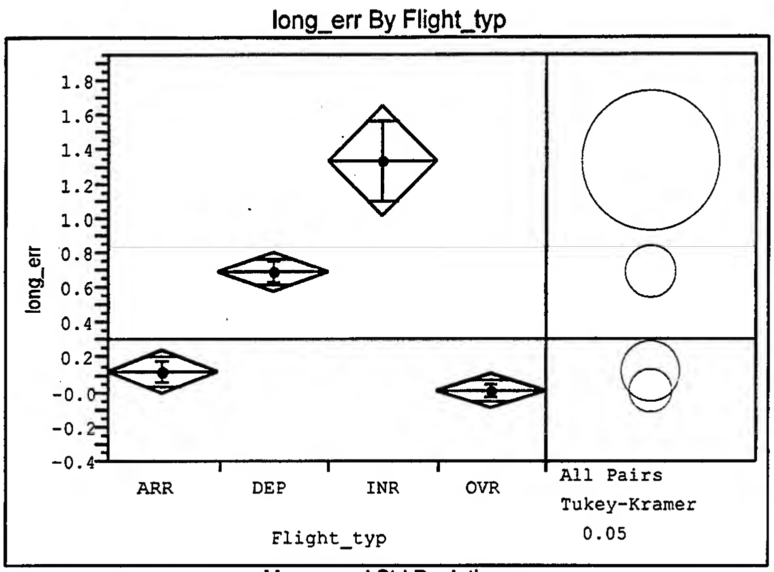
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 3524 | 5.157907 | 3.064321 | 3.050366 |
| DEP | 4601 | 6.276126 | 3.837585 | 3.498012 |
| INR | 587 | 6.734253 | 3.831845 | 3.796311 |
| OVR | 6069 | 4.393789 | 1.846023 | 1.841193 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 39.4011 | 3 | 14777 | <.0001 |
| Brown-Forsythe | 136.6233 | 3 | 14777 | <.0001 |
| Levene | 193.4383 | 3 | 14777 | <.0001 |
| Bartlett | 252.3342 | 3 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 64.7453 | 3 | 2536.2 | <.0001 |

**Figure A.2- 78 Statistical Tests for Lateral Error and Flight Type at Look Ahead Time 600 for Samples at Altitudes Above 18,000 Feet**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 3524 | 0.13325 | 4.05382 | 0.06829 |
| DEP | 4601 | 0.71609 | 4.65847 | 0.06868 |
| INR | 587 | 1.33758 | 5.86761 | 0.24218 |
| OVR | 6069 | 0.02175 | 3.46395 | 0.04446 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | INR | DEP | ARR | OVR |
|---|---|---|---|---|
| INR | 0.00000 | 0.62149 | 1.20433 | 1.31583 |
| DEP | -0.62149 | 0.00000 | 0.58284 | 0.69434 |
| ARR | -1.20433 | -0.58284 | 0.00000 | 0.11150 |
| OVR | -1.31583 | -0.69434 | -0.11150 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q*=2.56932

| Abs(Dif)-LSD | INR | DEP | ARR | OVR |
|---|---|---|---|---|
| INR | -0.61774 | 0.157654 | 0.732544 | 0.858385 |
| DEP | 0.157654 | -0.22065 | 0.345935 | 0.487465 |
| ARR | 0.732544 | 0.345935 | -0.25212 | -0.11264 |
| OVR | 0.858385 | 0.487465 | -0.11264 | -0.19212 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 3524 | 4.053821 | 2.466797 | 2.465175 |
| DEP | 4601 | 4.658474 | 3.302148 | 3.269237 |
| INR | 587 | 5.867611 | 3.990781 | 3.931556 |
| OVR | 6069 | 3.463951 | 2.016506 | 2.015870 |

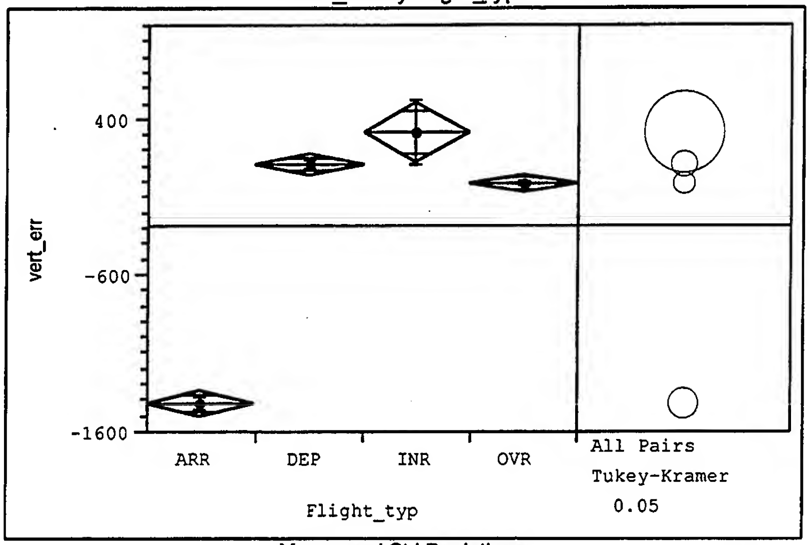
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 33.1286 | 3 | 14777 | <.0001 |
| Brown-Forsythe | 174.4498 | 3 | 14777 | <.0001 |
| Levene | 187.8547 | 3 | 14777 | <.0001 |
| Bartlett | 222.3397 | 3 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 31.6284 | 3 | 2521.5 | <.0001 |

**Figure A.2- 79 Statistical Tests for Longitudinal Error and Flight Type at Look Ahead Time 600 for Samples at Altitudes Above 18,000 Feet**

vert_err By Flight_typ




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 3524 | -1413.52 | 3060.83 | 51.56 |
| DEP | 4601 | 125.61 | 2690.82 | 39.67 |
| INR | 587 | 322.53 | 5126.08 | 211.58 |
| OVR | 6069 | -1.04 | 1404.76 | 18.03 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | INR | DEP | OVR | ARR |
|---|---|---|---|---|
| INR | 0.00 | 196.93 | 323.57 | 1736.06 |
| DEP | -196.93 | 0.00 | 126.64 | 1539.13 |
| OVR | -323.57 | -126.64 | 0.00 | 1412.48 |
| ARR | -1736.06 | -1539.13 | -1412.48 | 0.00 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q*=2.56932

| Abs(Dif)-LSD | INR | DEP | OVR | ARR |
|---|---|---|---|---|
| INR | -377.62 | -86.61 | 43.94 | 1447.66 |
| DEP | -86.61 | -134.88 | 0.18 | 1394.31 |
| OVR | 43.94 | 0.18 | -117.44 | 1275.47 |
| ARR | 1447.66 | 1394.31 | 1275.47 | -154.12 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

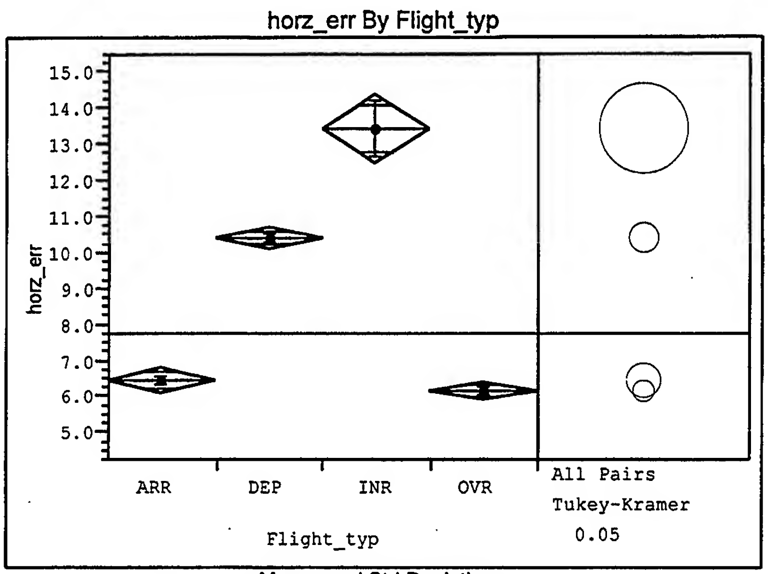
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 3524 | 3060.829 | 2252.792 | 1981.425 |
| DEP | 4601 | 2690.818 | 1465.116 | 1409.533 |
| INR | 587 | 5126.078 | 2868.165 | 2698.065 |
| OVR | 6069 | 1404.760 | 392.628 | 391.851 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 201.6230 | 3 | 14777 | <.0001 |
| Brown-Forsythe | 517.0105 | 3 | 14777 | 0.0000 |
| Levene | 798.2990 | 3 | 14777 | 0.0000 |
| Bartlett | 1420.3592 | 3 | ? | 0.0000 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 238.2345 | 3 | 2394.6 | <.0001 |

**Figure A.2- 80 Statistical Tests for Vertical Error and Flight Type at Look Ahead Time 600 for Samples at Altitudes Above 18,000 Feet**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 1595 | 6.4839 | 6.4759 | 0.16215 |
| DEP | 2511 | 10.4451 | 8.2364 | 0.16437 |
| INR | 262 | 13.4387 | 13.1882 | 0.81477 |
| OVR | 3806 | 6.2038 | 8.2718 | 0.13408 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | INR | DEP | ARR | OVR |
|---|---|---|---|---|
| INR | 0.00000 | 2.99359 | 6.95483 | 7.23489 |
| DEP | -2.99359 | 0.00000 | 3.96124 | 4.24130 |
| ARR | -6.95483 | -3.96124 | 0.00000 | 0.28006 |
| OVR | -7.23489 | -4.24130 | -0.28006 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q*=2.56956

| Abs(Dif)-LSD | INR | DEP | ARR | OVR |
|---|---|---|---|---|
| INR | -1.83002 | 1.63373 | 5.55857 | 5.89707 |
| DEP | 1.63373 | -0.59113 | 3.29058 | 3.70279 |
| ARR | 5.55857 | 3.29058 | -0.74170 | -0.34471 |
| OVR | 5.89707 | 3.70279 | -0.34471 | -0.48015 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

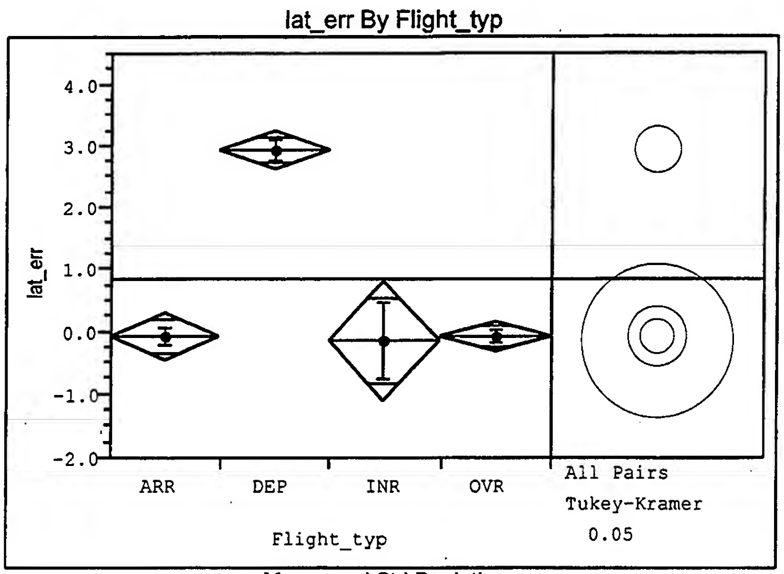
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 1595 | 6.47587 | 4.409969 | 4.096753 |
| DEP | 2511 | 8.23636 | 6.431127 | 6.254751 |
| INR | 262 | 13.18822 | 9.319455 | 8.557274 |
| OVR | 3806 | 8.27178 | 5.267627 | 4.581328 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 24.6861 | 3 | 8170 | <.0001 |
| Brown-Forsythe | 66.9528 | 3 | 8170 | <.0001 |
| Levene | 78.2751 | 3 | 8170 | <.0001 |
| Bartlett | 106.2329 | 3 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 168.6419 | 3 | 1147.4 | <.0001 |

**Figure A.2- 81 Statistical Tests for Horizontal Error and Flight Type at Look Ahead Time 1200 for Samples at Altitudes Above 18,000 Feet**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 1595 | -0.05141 | 5.9488 | 0.14895 |
| DEP | 2511 | 2.94013 | 9.5544 | 0.19067 |
| INR | 262 | -0.14939 | 10.0511 | 0.62096 |
| OVR | 3806 | -0.05280 | 7.7632 | 0.12584 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | DEP | ARR | OVR | INR |
|---|---|---|---|---|
| DEP | 0.00000 | 2.99153 | 2.99293 | 3.08951 |
| ARR | -2.99153 | 0.00000 | 0.00139 | 0.09798 |
| OVR | -2.99293 | -0.00139 | 0.00000 | 0.09659 |
| INR | -3.08951 | -0.09798 | -0.09659 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q*=2.56956

| Abs(Dif)-LSD | DEP | ARR | OVR | INR |
|---|---|---|---|---|
| DEP | -0.59024 | 2.32189 | 2.45524 | 1.73171 |
| ARR | 2.32189 | -0.74058 | -0.62242 | -1.29617 |
| OVR | 2.45524 | -0.62242 | -0.47942 | -1.23921 |
| INR | 1.73171 | -1.29617 | -1.23921 | -1.82726 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 1595 | 5.94877 | 3.592642 | 3.591725 |
| DEP | 2511 | 9.55439 | 6.622102 | 6.128857 |
| INR | 262 | 10.05110 | 5.673617 | 5.655618 |
| OVR | 3806 | 7.76318 | 3.226425 | 3.226131 |

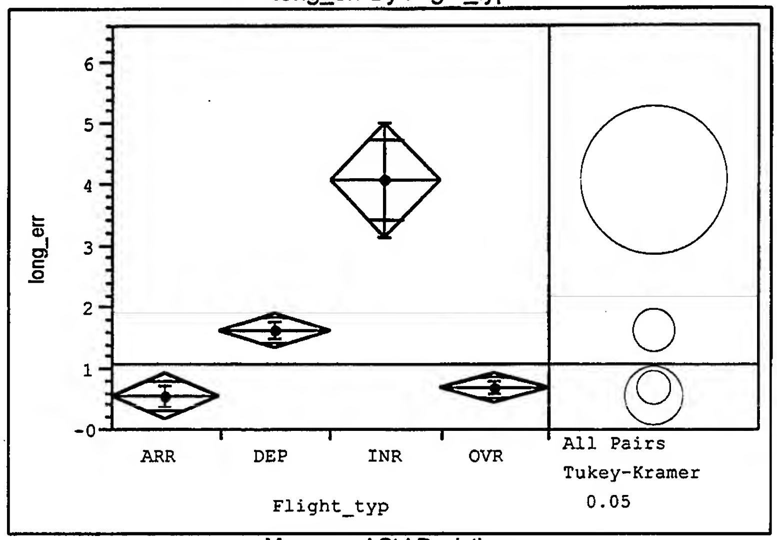
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 19.3541 | 3 | 8170 | <.0001 |
| Brown-Forsythe | 96.5331 | 3 | 8170 | <.0001 |
| Levene | 143.5206 | 3 | 8170 | <.0001 |
| Bartlett | 148.0216 | 3 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 65.8062 | 3 | 1160.8 | <.0001 |

**Figure A.2- 82 Statistical Tests for Lateral Error and Flight Type at Look Ahead Time 1200 for Samples at Altitudes Above 18,000 Feet**

long_err By Flight_typ




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 1595 | 0.19382 | 6.9697 | 0.17451 |
| DEP | 2511 | 1.30713 | 8.6798 | 0.17322 |
| INR | 262 | 3.71569 | 15.5021 | 0.95772 |
| OVR | 3806 | 0.32461 | 6.8224 | 0.11059 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | INR | DEP | OVR | ARR |
|---|---|---|---|---|
| INR | 0.00000 | 2.40856 | 3.39107 | 3.52186 |
| DEP | -2.40856 | 0.00000 | 0.98251 | 1.11331 |
| OVR | -3.39107 | -0.98251 | 0.00000 | 0.13079 |
| ARR | -3.52186 | -1.11331 | -0.13079 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q*=2.56956

| Abs(Dif)-LSD | INR | DEP | OVR | ARR |
|---|---|---|---|---|
| INR | -1.76742 | 1.09522 | 2.09901 | 2.17336 |
| DEP | 1.09522 | -0.57091 | 0.46243 | 0.46560 |
| OVR | 2.09901 | 0.46243 | -0.46372 | -0.47260 |
| ARR | 2.17336 | 0.46560 | -0.47260 | -0.71633 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 1595 | 6.96966 | 4.38399 | 4.38362 |
| DEP | 2511 | 8.67979 | 6.52416 | 6.47047 |
| INR | 262 | 15.50208 | 10.61387 | 10.47426 |
| OVR | 3806 | 6.82238 | 4.00888 | 4.00871 |

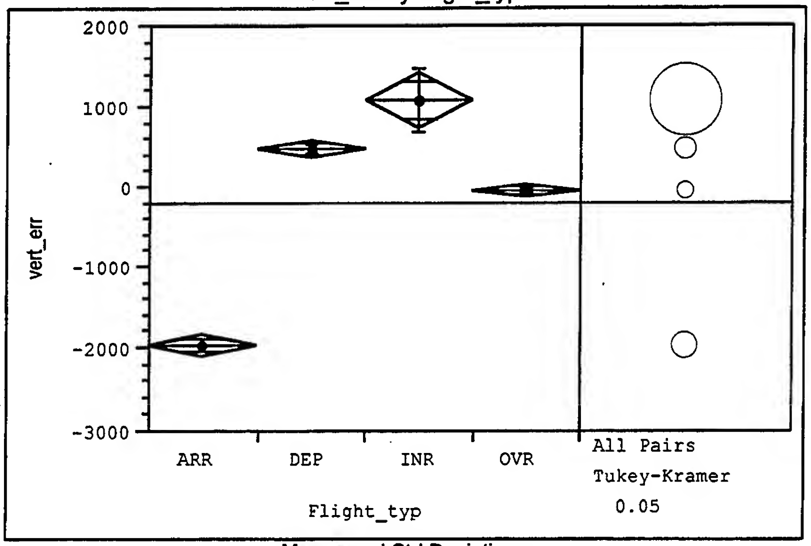
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 78.5880 | 3 | 8170 | <.0001 |
| Brown-Forsythe | 168.9026 | 3 | 8170 | <.0001 |
| Levene | 180.1406 | 3 | 8170 | <.0001 |
| Bartlett | 211.2908 | 3 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 12.7640 | 3 | 1123.5 | <.0001 |

**Figure A.2- 83 Statistical Tests for Longitudinal Error and Flight Type at Look Ahead Time 1200 for Samples at Altitudes Above 18,000 Feet**

vert_err By Flight_typ




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 1595 | -1946.08 | 3537.60 | 88.58 |
| DEP | 2511 | 507.25 | 3196.61 | 63.79 |
| INR | 262 | 1082.46 | 6391.57 | 394.87 |
| OVR | 3806 | -26.60 | 1904.24 | 30.87 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | INR | DEP | OVR | ARR |
|---|---|---|---|---|
| INR | 0.00 | 575.21 | 1109.06 | 3028.54 |
| DEP | -575.21 | 0.00 | 533.85 | 2453.33 |
| OVR | -1109.06 | -533.85 | 0.00 | 1919.48 |
| ARR | -3028.54 | -2453.33 | -1919.48 | 0.00 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q*=2.56956

| Abs(Dif)-LSD | INR | DEP | OVR | ARR |
|---|---|---|---|---|
| INR | -657.41 | 86.70 | 628.47 | 2526.96 |
| DEP | 86.70 | -212.36 | 340.40 | 2212.41 |
| OVR | 628.47 | 340.40 | -172.49 | 1695.05 |
| ARR | 2526.96 | 2212.41 | 1695.05 | -266.44 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 1595 | 3537.600 | 2717.032 | 2587.946 |
| DEP | 2511 | 3196.614 | 1763.663 | 1481.987 |
| INR | 262 | 6391.569 | 3902.425 | 3343.819 |
| OVR | 3806 | 1904.245 | 608.155 | 588.348 |

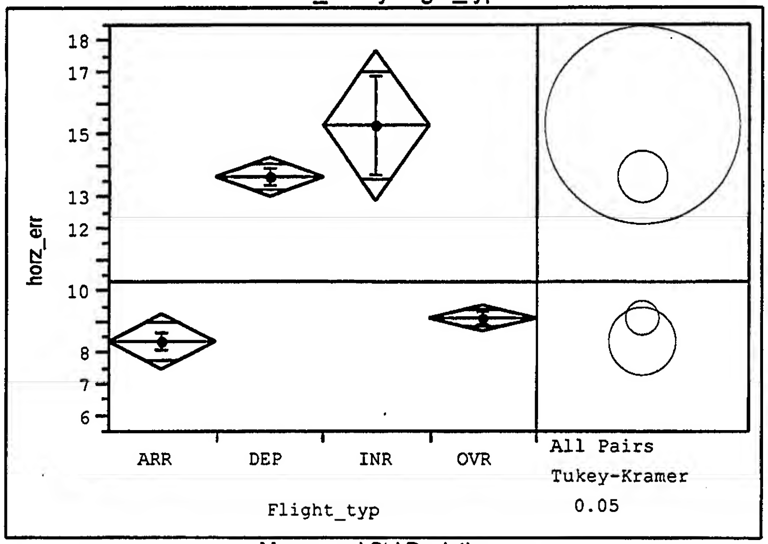
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 105.9061 | 3 | 8170 | <.0001 |
| Brown-Forsythe | 291.0796 | 3 | 8170 | <.0001 |
| Levene | 427.3650 | 3 | 8170 | <.0001 |
| Bartlett | 607.8525 | 3 | ? | 0.0000 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 179.6429 | 3 | 1084.8 | <.0001 |

**Figure A.2- 84 Statistical Tests for Vertical Error and Flight Type at Look Ahead Time 1200 for Samples at Altitudes Above 18,000 Feet**

horz_err By Flight_typ




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 568 | 8.3616 | 7.4698 | 0.3134 |
| DEP | 1051 | 13.6115 | 10.0271 | 0.3093 |
| INR | 76 | 15.3086 | 14.1192 | 1.6196 |
| OVR | 2217 | 9.1400 | 11.8309 | 0.2513 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | INR | DEP | OVR | ARR |
|---|---|---|---|---|
| INR | 0.00000 | 1.69707 | 6.16858 | 6.94694 |
| DEP | -1.69707 | 0.00000 | 4.47151 | 5.24987 |
| OVR | -6.16858 | -4.47151 | 0.00000 | 0.77836 |
| ARR | -6.94694 | -5.24987 | -0.77836 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q*=2.57014

| Abs(Dif)-LSD | INR | DEP | OVR | ARR |
|---|---|---|---|---|
| INR | -4.53485 | -1.62347 | 2.90746 | 3.53252 |
| DEP | -1.62347 | -1.21946 | 3.42460 | 3.79407 |
| OVR | 2.90746 | 3.42460 | -0.83963 | -0.53629 |
| ARR | 3.53252 | 3.79407 | -0.53629 | -1.65881 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

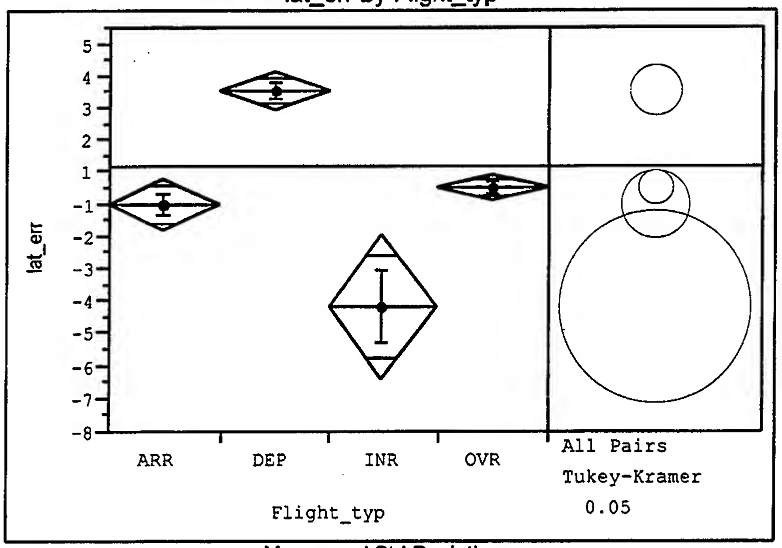
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 568 | 7.46975 | 5.39484 | 5.07133 |
| DEP | 1051 | 10.02706 | 7.94571 | 7.84246 |
| INR | 76 | 14.11919 | 10.93628 | 10.26502 |
| OVR | 2217 | 11.83086 | 7.65672 | 6.71364 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 9.2485 | 3 | 3908 | <.0001 |
| Brown-Forsythe | 15.2901 | 3 | 3908 | <.0001 |
| Levene | 19.9114 | 3 | 3908 | <.0001 |
| Bartlett | 61.5966 | 3 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 60.9921 | 3 | 342.04 | <.0001 |

**Figure A.2- 85 Statistical Tests for Horizontal Error and Flight Type at Look Ahead Time 1800 for Samples at Altitudes Above 18,000 Feet**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 568 | -0.49947 | 8.2107 | 0.3445 |
| DEP | 1051 | 3.07868 | 10.4293 | 0.3217 |
| INR | 76 | -3.63685 | 9.8520 | 1.1301 |
| OVR | 2217 | 0.04260 | 10.5933 | 0.2250 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | DEP | OVR | ARR | INR |
|---|---|---|---|---|
| DEP | 0.00000 | 3.03608 | 3.57815 | 6.71553 |
| OVR | -3.03608 | 0.00000 | 0.54207 | 3.67945 |
| ARR | -3.57815 | -0.54207 | 0.00000 | 3.13738 |
| INR | -6.71553 | -3.67945 | -3.13738 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q*=2.57014

| Abs(Dif)-LSD | DEP | OVR | ARR | INR |
|---|---|---|---|---|
| DEP | -1.14612 | 2.05213 | 2.20991 | 3.59470 |
| OVR | 2.05213 | -0.78913 | -0.69351 | 0.61446 |
| ARR | 2.20991 | -0.69351 | -1.55904 | -0.07168 |
| INR | 3.59470 | 0.61446 | -0.07168 | -4.26211 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 568 | 8.21067 | 4.950546 | 4.861906 |
| DEP | 1051 | 10.42935 | 7.087868 | 6.798501 |
| INR | 76 | 9.85200 | 6.609563 | 6.060208 |
| OVR | 2217 | 10.59330 | 4.557133 | 4.547427 |

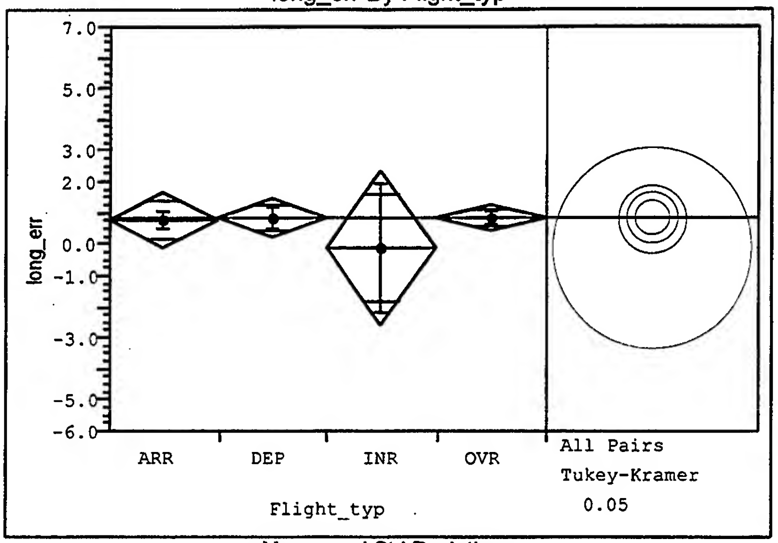
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 1.6793 | 3 | 3908 | 0.1692 |
| Brown-Forsythe | 16.0530 | 3 | 3908 | <.0001 |
| Levene | 21.2937 | 3 | 3908 | <.0001 |
| Bartlett | 18.0091 | 3 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 29.7981 | 3 | 344.36 | <.0001 |

**Figure A.2- 86 Statistical Tests for Lateral Error and Flight Type at Look Ahead Time 1800 for Samples at Altitudes Above 18,000 Feet**

long_err By Flight_typ




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 568 | 0.831732 | 7.5815 | 0.3181 |
| DEP | 1051 | 0.879796 | 12.9212 | 0.3986 |
| INR | 76 | -0.08566 | 18.0653 | 2.0722 |
| OVR | 2217 | 0.862583 | 10.5158 | 0.2233 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | DEP | OVR | ARR | INR |
|---|---|---|---|---|
| DEP | 0.000000 | 0.017213 | 0.048064 | 0.965453 |
| OVR | -0.01721 | 0.000000 | 0.030851 | 0.948240 |
| ARR | -0.04806 | -0.03085 | 0.000000 | 0.917389 |
| INR | -0.96545 | -0.94824 | -0.91739 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q*=2.57014

| Abs(Dif)-LSD | DEP | OVR | ARR | INR |
|---|---|---|---|---|
| DEP | -1.23921 | -1.04666 | -1.43131 | -2.40886 |
| OVR | -1.04666 | -0.85322 | -1.30509 | -2.36569 |
| ARR | -1.43131 | -1.30509 | -1.68567 | -2.55232 |
| INR | -2.40886 | -2.36569 | -2.55232 | -4.60828 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

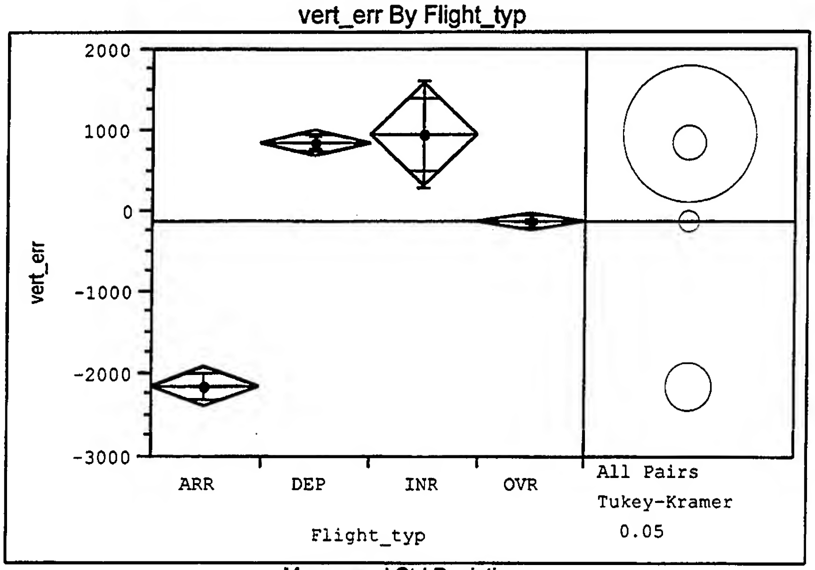
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 568 | 7.58151 | 5.39605 | 5.39570 |
| DEP | 1051 | 12.92122 | 9.68734 | 9.52229 |
| INR | 76 | 18.06533 | 12.12689 | 11.87389 |
| OVR | 2217 | 10.51581 | 6.09995 | 6.08753 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 21.4623 | 3 | 3908 | <.0001 |
| Brown-Forsythe | 55.4863 | 3 | 3908 | <.0001 |
| Levene | 62.1825 | 3 | 3908 | <.0001 |
| Bartlett | 82.0415 | 3 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 0.0717 | 3 | 336.84 | 0.9751 |

**Figure A.2- 87 Statistical Tests for Longitudinal Error and Flight Type at Look Ahead Time 1800 for Samples at Altitudes Above 18,000 Feet**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ARR | 568 | -2134.48 | 4030.35 | 169.11 |
| DEP | 1051 | 854.48 | 3332.79 | 102.80 |
| INR | 76 | 954.04 | 5918.06 | 678.85 |
| OVR | 2217 | -118.67 | 2096.60 | 44.53 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | INR | DEP | OVR | ARR |
|---|---|---|---|---|
| INR | 0.00 | 99.56 | 1072.71 | 3088.51 |
| DEP | -99.56 | 0.00 | 973.15 | 2988.95 |
| OVR | -1072.71 | -973.15 | 0.00 | 2015.80 |
| ARR | -3088.51 | -2988.95 | -2015.80 | 0.00 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q*=2.57014

| Abs(Dif)-LSD | INR | DEP | OVR | ARR |
|---|---|---|---|---|
| INR | -1215.97 | -790.81 | 198.27 | 2172.97 |
| DEP | -790.81 | -326.99 | 692.43 | 2598.60 |
| OVR | 198.27 | 692.43 | -225.14 | 1663.30 |
| ARR | 2172.97 | 2598.60 | 1663.30 | -444.79 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ARR | 568 | 4030.345 | 3168.840 | 3059.420 |
| DEP | 1051 | 3332.793 | 2010.625 | 1601.063 |
| INR | 76 | 5918.064 | 4046.664 | 3628.069 |
| OVR | 2217 | 2096.601 | 813.231 | 724.523 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 43.6092 | 3 | 3908 | <.0001 |
| Brown-Forsythe | 157.1113 | 3 | 3908 | <.0001 |
| Levene | 214.4960 | 3 | 3908 | <.0001 |
| Bartlett | 236.1195 | 3 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 77.4440 | 3 | 322.02 | <.0001 |

**Figure A.2- 88 Statistical Tests for Vertical Error and Flight Type at Look Ahead Time 1800 for Samples at Altitudes Above 18,000 Feet**

## *A.2.3 Horizaontal Phase of Flight Per Look Ahead Time*

### A.2.3.1 Summary Tables

| Look Ahead Time | 0 | | 300 | |
|---|---|---|---|---|
| Horizontal Phase of Flight | Straight | Turn | Straight | Turn |
| Sample Quantity | 27295 | 5314 | 22892 | 4271 |
| Avg. Horz. Error | 0.26 | 0.33 | 2.59 | 2.88 |
| Stddev. Horz. Error | 0.83 | 0.92 | 3.18 | 3.28 |
| Max. Horz. Error | 48.02 | 25.79 | 88.45 | 32.87 |
| Min. Horz. Error | 0 | 0 | 0 | 0.01 |
| Avg. Lat. Error | 0 | 0 | 0.05 | -0.12 |
| Stddev. Lat. Error | 0.46 | 0.44 | 3.29 | 3.36 |
| Max. Lat. Error | 22.88 | 11.48 | 46.61 | 20.75 |
| Min. Lat. Error | -15.57 | -8.26 | -46.12 | -30.48 |
| Avg. Abs. Lat. Error | 0.12 | 0.17 | 1.71 | 1.83 |
| Stddev. Abs. Lat. Error | 0.44 | 0.4 | 2.81 | 2.82 |
| Max. Abs. Lat. Error | 22.88 | 11.48 | 46.61 | 30.48 |
| Min. Abs. Lat. Error | 0 | 0 | 0 | 0 |
| Avg. Long. Error | -0.04 | -0.11 | -0.03 | -0.23 |
| Stddev. Long. Error | 0.74 | 0.87 | 2.44 | 2.77 |
| Max. Long. Error | 47.54 | 17.84 | 46.01 | 22.74 |
| Min. Long. Error | -31.16 | -23.09 | -87.99 | -26.03 |
| Avg. Abs. Long. Error | 0.2 | 0.24 | 1.44 | 1.72 |
| Stddev. Abs. Long. Error | 0.72 | 0.85 | 1.98 | 2.19 |
| Max. Abs. Long. Error | 47.54 | 23.09 | 87.99 | 26.03 |
| Min. Abs. Long. Error | 0 | 0 | 0 | 0 |
| Avg. Vert. Error | -92.51 | -131.26 | -487.15 | -746.29 |
| Stddev. Vert. Error | 767.14 | 894.17 | 2132.89 | 2287.29 |
| Max. Vert. Error | 18889 | 5200 | 27290 | 16460.38 |
| Min. Vert. Error | -31025 | -31466.5 | -24677 | -17950 |
| Avg. Abs. Vert. Error | 149 | 179.68 | 1021.07 | 1278.96 |
| Stddev. Abs. Vert. Error | 758.19 | 885.71 | 1934.92 | 2037.81 |
| Max. Abs. Vert. Error | 31025 | 31466.46 | 27290 | 17950 |
| Min. Abs. Vert. Error | 0 | 0 | 0 | 0 |
| Avg. Slant Range Error | 0.27 | 0.34 | 2.62 | 2.91 |
| Stddev. Slant Range Error | 0.84 | 0.93 | 3.18 | 3.27 |
| Max. Slant Range Error | 48.03 | 25.79 | 88.56 | 32.89 |
| Min. Slant Range Error | 0 | 0 | 0.01 | 0.01 |

**Figure A.2- 89 Descriptive Statistics for Horizontal Phase of Flight per Look Ahead Time for Samples at All Altitudes**

| Look Ahead Time | 600 | | 900 | |
|---|---|---|---|---|
| Horizontal Phase of Flight | Straight | Turn | Straight | Turn |
| Sample Quantity | 18406 | 3502 | 14224 | 2717 |
| Avg. Horz. Error | 4.42 | 5.1 | 6.1 | 6.78 |
| Stddev. Horz. Error | 4.85 | 5.44 | 6.38 | 7.41 |
| Max. Horz. Error | 67.08 | 65.69 | 85.13 | 101.09 |
| Min. Horz. Error | 0.01 | 0.02 | 0.01 | 0.05 |
| Avg. Lat. Error | 0.27 | 0.05 | 0.5 | 0.25 |
| Stddev. Lat. Error | 4.94 | 5.5 | 6.24 | 6.78 |
| Max. Lat. Error | 55.5 | 38.94 | 60.84 | 54.78 |
| Min. Lat. Error | -38.27 | -34.2 | -43.96 | -64.27 |
| Avg. Abs. Lat. Error | 2.6 | 2.97 | 3.28 | 3.62 |
| Stddev. Abs. Lat. Error | 4.21 | 4.63 | 5.34 | 5.73 |
| Max. Abs. Lat. Error | 55.5 | 38.94 | 60.84 | 64.27 |
| Min. Abs. Lat. Error | 0 | 0 | 0 | 0 |
| Avg. Long. Error | 0.35 | 0.01 | 0.7 | 0.34 |
| Stddev. Long. Error | 4.3 | 5.04 | 6.18 | 7.4 |
| Max. Long. Error | 59.63 | 25.83 | 49.55 | 58.31 |
| Min. Long. Error | -59.4 | -59.56 | -76.98 | -83.04 |
| Avg. Abs. Long. Error | 2.75 | 3.25 | 4.05 | 4.6 |
| Stddev. Abs. Long. Error | 3.32 | 3.85 | 4.72 | 5.8 |
| Max. Abs. Long. Error | 59.63 | 59.56 | 76.98 | 83.04 |
| Min. Abs. Long. Error | 0 | 0 | 0 | 0 |
| Avg. Vert. Error | -684.1 | -1157.81 | -793.99 | -1535.62 |
| Stddev. Vert. Error | 2795.7 | 3059.21 | 3330.87 | 3437.51 |
| Max. Vert. Error | 28990 | 15000 | 29003 | 18825 |
| Min. Vert. Error | -26868 | -23629.6 | -32426 | -21566 |
| Avg. Abs. Vert. Error | 1436.1 | 1859.4 | 1701.93 | 2222.37 |
| Stddev. Abs. Vert. Error | 2494.28 | 2690.97 | 2971.26 | 3038.87 |
| Max. Abs. Vert. Error | 28990 | 23629.62 | 32426 | 21566 |
| Min. Abs. Vert. Error | 0 | 0 | 0 | 0 |
| Avg. Slant Range Error | 4.45 | 5.14 | 6.14 | 6.83 |
| Stddev. Slant Range Error | 4.84 | 5.42 | 6.37 | 7.39 |
| Max. Slant Range Error | 67.09 | 65.69 | 85.13 | 101.09 |
| Min. Slant Range Error | 0.01 | 0.04 | 0.01 | 0.06 |

**Figure A.2- 90 Descriptive Statistics for Horizontal Phase of Flight per Look Ahead Time for Samples at All Altitudes**

| Look Ahead Time | 1200 | | 1500 | |
|---|---|---|---|---|
| Horizontal Phase of Flight | Straight | Turn | Straight | Turn |
| Sample Quantity | 10850 | 2071 | 7738 | 1523 |
| Avg. Horz. Error | 7.78 | 8.03 | 9.37 | 9.56 |
| Stddev. Horz. Error | 8.05 | 8.45 | 9.8 | 9.53 |
| Max. Horz. Error | 82.64 | 103.04 | 94.14 | 66.7 |
| Min. Horz. Error | 0.01 | 0.08 | 0.03 | 0.09 |
| Avg. Lat. Error | 0.57 | 0.51 | 0.53 | 0.12 |
| Stddev. Lat. Error | 7.52 | 7.14 | 8.67 | 7.88 |
| Max. Lat. Error | 76.1 | 51.81 | 85.67 | 58.08 |
| Min. Lat. Error | -55.56 | -46.57 | -65.63 | -58.18 |
| Avg. Abs. Lat. Error | 3.92 | 3.87 | 4.46 | 4.17 |
| Stddev. Abs. Lat. Error | 6.44 | 6.01 | 7.46 | 6.68 |
| Max. Abs. Lat. Error | 76.1 | 51.81 | 85.67 | 58.18 |
| Min. Abs. Lat. Error | 0 | 0 | 0 | 0 |
| Avg. Long. Error | 1.21 | 1.11 | 1.75 | 2.38 |
| Stddev. Long. Error | 8.19 | 9.14 | 10.26 | 10.7 |
| Max. Long. Error | 77.59 | 53.21 | 94.14 | 52.7 |
| Min. Long. Error | -74.98 | -94.35 | -73.71 | -64.82 |
| Avg. Abs. Long. Error | 5.4 | 5.78 | 6.7 | 7.25 |
| Stddev. Abs. Long. Error | 6.28 | 7.16 | 7.96 | 8.22 |
| Max. Abs. Long. Error | 77.59 | 94.35 | 94.14 | 64.82 |
| Min. Abs. Long. Error | 0 | 0 | 0 | 0.01 |
| Avg. Vert. Error | -933.03 | -1681.97 | -1012.68 | -1853.79 |
| Stddev. Vert. Error | 3506.8 | 3884.51 | 3697.58 | 3615.68 |
| Max. Vert. Error | 29003 | 28590 | 29003 | 12988 |
| Min. Vert. Error | -28868 | -26558 | -27901 | -21608.7 |
| Avg. Abs. Vert. Error | 1837.68 | 2481.46 | 1941.86 | 2467.18 |
| Stddev. Abs. Vert. Error | 3129.04 | 3429.17 | 3305.51 | 3228.16 |
| Max. Abs. Vert. Error | 29003 | 28590 | 29003 | 21608.72 |
| Min. Abs. Vert. Error | 0 | 0 | 0 | 0 |
| Avg. Slant Range Error | 7.82 | 8.08 | 9.41 | 9.6 |
| Stddev. Slant Range Error | 8.04 | 8.43 | 9.79 | 9.51 |
| Max. Slant Range Error | 82.64 | 103.05 | 94.14 | 66.71 |
| Min. Slant Range Error | 0.01 | 0.08 | 0.03 | 0.09 |

**Figure A.2- 91 Descriptive Statistics for Horizontal Phase of Flight per Look Ahead Time for Samples at All Altitudes**

| Look Ahead Time | 1800 | | | |
|---|---|---|---|---|
| Horizontal Phase of Flight | Straight | Turn | Straight | Turn |
| Sample Quantity | 5538 | 1119 | | |
| Avg. Horz. Error | 10.92 | 11.04 | | |
| Stddev. Horz. Error | 11.25 | 11.07 | | |
| Max. Horz. Error | 98.82 | 80.1 | | |
| Min. Horz. Error | 0.03 | 0.14 | | |
| Avg. Lat. Error | 0.4 | 0.72 | | |
| Stddev. Lat. Error | 9.5 | 8.82 | | |
| Max. Lat. Error | 86.54 | 80.05 | | |
| Min. Lat. Error | -62.21 | -51.12 | | |
| Avg. Abs. Lat. Error | 4.92 | 4.63 | | |
| Stddev. Abs. Lat. Error | 8.14 | 7.54 | | |
| Max. Abs. Lat. Error | 86.54 | 80.05 | | |
| Min. Abs. Lat. Error | 0 | 0 | | |
| Avg. Long. Error | 2.23 | 3.41 | | |
| Stddev. Long. Error | 12.26 | 12.43 | | |
| Max. Long. Error | 96.86 | 62.4 | | |
| Min. Long. Error | -78.6 | -64.47 | | |
| Avg. Abs. Long. Error | 8.06 | 8.45 | | |
| Stddev. Abs. Long. Error | 9.5 | 9.74 | | |
| Max. Abs. Long. Error | 96.86 | 64.47 | | |
| Min. Abs. Long. Error | 0 | 0.01 | | |
| Avg. Vert. Error | -1147.78 | -1854.55 | | |
| Stddev. Vert. Error | 3829.33 | 4008.78 | | |
| Max. Vert. Error | 29003 | 16996 | | |
| Min. Vert. Error | -29635 | -25934 | | |
| Avg. Abs. Vert. Error | 2075.72 | 2597.2 | | |
| Stddev. Abs. Vert. Error | 3416.44 | 3572.29 | | |
| Max. Abs. Vert. Error | 29635 | 25934 | | |
| Min. Abs. Vert. Error | 0 | 0 | | |
| Avg. Slant Range Error | 10.95 | 11.08 | | |
| Stddev. Slant Range Error | 11.23 | 11.05 | | |
| Max. Slant Range Error | 98.82 | 80.1 | | |
| Min. Slant Range Error | 0.03 | 0.14 | | |

**Figure A.2- 92 Descriptive Statistics for Horizontal Phase of Flight per Look Ahead Time for Samples at All Altitudes**

| Look Ahead Time | 0 | | 300 | |
|---|---|---|---|---|
| Horizontal Phase of Flight | Straight | Turn | Straight | Turn |
| Sample Quantity | 18689 | 2520 | 16359 | 2092 |
| Avg. Horz. Error | 0.23 | 0.36 | 2.46 | 2.87 |
| Stddev. Horz. Error | 0.71 | 1.01 | 3.29 | 3.46 |
| Max. Horz. Error | 48.02 | 25.79 | 88.45 | 32.87 |
| Min. Horz. Error | 0 | 0 | 0 | 0.01 |
| Avg. Lat. Error | 0 | 0 | 0.08 | -0.13 |
| Stddev. Lat. Error | 0.4 | 0.46 | 3.41 | 3.78 |
| Max. Lat. Error | 22.88 | 11.48 | 46.61 | 20.75 |
| Min. Lat. Error | -15.57 | -8.26 | -46.12 | -30.48 |
| Avg. Abs. Lat. Error | 0.1 | 0.19 | 1.68 | 1.97 |
| Stddev. Abs. Lat. Error | 0.39 | 0.43 | 2.98 | 3.22 |
| Max. Abs. Lat. Error | 22.88 | 11.48 | 46.61 | 30.48 |
| Min. Abs. Lat. Error | 0 | 0 | 0 | 0 |
| Avg. Long. Error | -0.03 | -0.12 | 0.06 | -0.05 |
| Stddev. Long. Error | 0.63 | 0.95 | 2.28 | 2.43 |
| Max. Long. Error | 47.54 | 17.84 | 46.01 | 10.03 |
| Min. Long. Error | -31.16 | -23.09 | -87.99 | -16.55 |
| Avg. Abs. Long. Error | 0.18 | 0.26 | 1.29 | 1.55 |
| Stddev. Abs. Long. Error | 0.6 | 0.93 | 1.88 | 1.87 |
| Max. Abs. Long. Error | 47.54 | 23.09 | 87.99 | 16.55 |
| Min. Abs. Long. Error | 0 | 0 | 0 | 0 |
| Avg. Vert. Error | -13.84 | -44.2 | -115.47 | -361.89 |
| Stddev. Vert. Error | 485.48 | 593.33 | 1728.77 | 2112.63 |
| Max. Vert. Error | 18889 | 5200 | 27290 | 14600 |
| Min. Vert. Error | -21500 | -16406.8 | -18228 | -17950 |
| Avg. Abs. Vert. Error | 69.58 | 93.34 | 698.19 | 1021.31 |
| Stddev. Abs. Vert. Error | 480.67 | 587.61 | 1585.71 | 1884.32 |
| Max. Abs. Vert. Error | 21500 | 16406.83 | 27290 | 17950 |
| Min. Abs. Vert. Error | 0 | 0 | 0 | 0 |
| Avg. Slant Range Error | 0.24 | 0.36 | 2.48 | 2.89 |
| Stddev. Slant Range Error | 0.72 | 1.01 | 3.29 | 3.45 |
| Max. Slant Range Error | 48.03 | 25.79 | 88.56 | 32.89 |
| Min. Slant Range Error | 0 | 0 | 0.01 | 0.01 |

**Figure A.2- 93 Descriptive Statistics for Horizontal Phase of Flight per Look Ahead Time for Samples at Altitudes Above 18,000 Feet**

| Look Ahead Time | 600 | | 900 | |
|---|---|---|---|---|
| Horizontal Phase of Flight | Straight | Turn | Straight | Turn |
| Sample Quantity | 13146 | 1661 | 10001 | 1216 |
| Avg. Horz. Error | 4.29 | 5.34 | 6.04 | 6.84 |
| Stddev. Horz. Error | 5.04 | 5.91 | 6.62 | 7.81 |
| Max. Horz. Error | 67.08 | 43.12 | 75.25 | 58.36 |
| Min. Horz. Error | 0.01 | 0.02 | 0.01 | 0.09 |
| Avg. Lat. Error | 0.36 | 0.07 | 0.71 | 0.31 |
| Stddev. Lat. Error | 5.21 | 6.43 | 6.75 | 8.08 |
| Max. Lat. Error | 55.5 | 38.94 | 60.84 | 54.78 |
| Min. Lat. Error | -38.27 | -34.2 | -43.96 | -38.45 |
| Avg. Abs. Lat. Error | 2.63 | 3.46 | 3.45 | 4.26 |
| Stddev. Abs. Lat. Error | 4.51 | 5.42 | 5.84 | 6.88 |
| Max. Abs. Lat. Error | 55.5 | 38.94 | 60.84 | 54.78 |
| Min. Abs. Lat. Error | 0 | 0 | 0 | 0 |
| Avg. Long. Error | 0.34 | 0.1 | 0.49 | -0.06 |
| Stddev. Long. Error | 4.06 | 4.71 | 5.84 | 6.51 |
| Max. Long. Error | 59.63 | 23.35 | 49.55 | 58.31 |
| Min. Long. Error | -29.72 | -22.22 | -61.99 | -29.54 |
| Avg. Abs. Long. Error | 2.54 | 3.07 | 3.76 | 4.07 |
| Stddev. Abs. Long. Error | 3.18 | 3.57 | 4.49 | 5.08 |
| Max. Abs. Long. Error | 59.63 | 23.35 | 61.99 | 58.31 |
| Min. Abs. Long. Error | 0 | 0 | 0 | 0 |
| Avg. Vert. Error | -227.61 | -738.37 | -170.96 | -1060.4 |
| Stddev. Vert. Error | 2513.8 | 3125.02 | 2919.33 | 3630.59 |
| Max. Vert. Error | 28990 | 15000 | 29003 | 18825 |
| Min. Vert. Error | -16708 | -16406.8 | -20550 | -19945.7 |
| Avg. Abs. Vert. Error | 1106.31 | 1740.02 | 1259.94 | 2077.59 |
| Stddev. Abs. Vert. Error | 2268.69 | 2698.48 | 2638.96 | 3160.17 |
| Max. Abs. Vert. Error | 28990 | 16406.83 | 29003 | 19945.74 |
| Min. Abs. Vert. Error | 0 | 0 | 0 | 0 |
| Avg. Slant Range Error | 4.32 | 5.38 | 6.07 | 6.9 |
| Stddev. Slant Range Error | 5.03 | 5.9 | 6.62 | 7.78 |
| Max. Slant Range Error | 67.09 | 43.12 | 75.4 | 58.36 |
| Min. Slant Range Error | 0.01 | 0.04 | 0.01 | 0.09 |

**Figure A.2- 94 Descriptive Statistics for Horizontal Phase of Flight per Look Ahead Time for Samples at Altitudes Above 18,000 Feet**

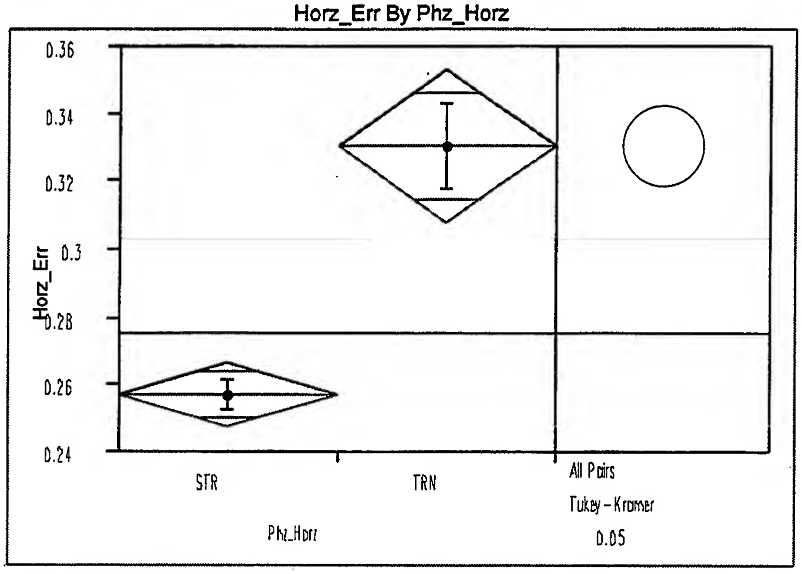
| Look Ahead Time | 1200 | | 1500 | |
|---|---|---|---|---|
| Horizontal Phase of Flight | Straight | Turn | Straight | Turn |
| Sample Quantity | 7290 | 899 | 5065 | 640 |
| Avg. Horz. Error | 7.75 | 8.12 | 9.15 | 8.98 |
| Stddev. Horz. Error | 8.35 | 9.03 | 9.89 | 9.37 |
| Max. Horz. Error | 78.4 | 86.73 | 87.22 | 66.7 |
| Min. Horz. Error | 0.01 | 0.08 | 0.03 | 0.09 |
| Avg. Lat. Error | 0.88 | 0.71 | 0.88 | -0.15 |
| Stddev. Lat. Error | 8.26 | 8.16 | 9.53 | 9.13 |
| Max. Lat. Error | 76.1 | 51.81 | 85.67 | 58.08 |
| Min. Lat. Error | -55.56 | -46.57 | -65.63 | -58.18 |
| Avg. Abs. Lat. Error | 4.25 | 4.43 | 4.81 | 4.93 |
| Stddev. Abs. Lat. Error | 7.14 | 6.89 | 8.27 | 7.68 |
| Max. Abs. Lat. Error | 76.1 | 51.81 | 85.67 | 58.18 |
| Min. Abs. Lat. Error | 0 | 0 | 0 | 0 |
| Avg. Long. Error | 0.76 | 0.21 | 0.84 | 0.52 |
| Stddev. Long. Error | 7.76 | 8.97 | 9.45 | 9.21 |
| Max. Long. Error | 77.59 | 53.21 | 63.91 | 45.31 |
| Min. Long. Error | -48.76 | -85.87 | -61.99 | -43.79 |
| Avg. Abs. Long. Error | 5.02 | 5.37 | 6.11 | 5.95 |
| Stddev. Abs. Long. Error | 5.97 | 7.18 | 7.26 | 7.04 |
| Max. Abs. Long. Error | 77.59 | 85.87 | 63.91 | 45.31 |
| Min. Abs. Long. Error | 0 | 0.03 | 0 | 0.01 |
| Avg. Vert. Error | -122.61 | -837.67 | -87.3 | -920.05 |
| Stddev. Vert. Error | 2952.86 | 3769.17 | 2915.69 | 3442.38 |
| Max. Vert. Error | 29003 | 28590 | 29003 | 12988 |
| Min. Vert. Error | -19633 | -17533 | -20550 | -19924.8 |
| Avg. Abs. Vert. Error | 1255.15 | 2063.47 | 1248.58 | 1902.22 |
| Stddev. Abs. Vert. Error | 2675.6 | 3262.89 | 2636.21 | 3012.25 |
| Max. Abs. Vert. Error | 29003 | 28590 | 29003 | 19924.8 |
| Min. Abs. Vert. Error | 0 | 0 | 0 | 0 |
| Avg. Slant Range Error | 7.78 | 8.16 | 9.17 | 9.02 |
| Stddev. Slant Range Error | 8.34 | 9.01 | 9.88 | 9.35 |
| Max. Slant Range Error | 78.4 | 86.86 | 87.23 | 66.71 |
| Min. Slant Range Error | 0.01 | 0.08 | 0.03 | 0.09 |

**Figure A.2- 95 Descriptive Statistics for Horizontal Phase of Flight per Look Ahead Time for Samples at Altitudes Above 18,000 Feet**

| Look Ahead Time | 1800 | | | |
|---|---|---|---|---|
| Horizontal Phase of Flight | Straight | Turn | Straight | Turn |
| Sample Quantity | 3471 | 446 | | |
| Avg. Horz. Error | 10.24 | 11.15 | | |
| Stddev. Horz. Error | 10.95 | 12.07 | | |
| Max. Horz. Error | 87.65 | 80.1 | | |
| Min. Horz. Error | 0.03 | 0.16 | | |
| Avg. Lat. Error | 0.74 | 0.46 | | |
| Stddev. Lat. Error | 10.21 | 11.2 | | |
| Max. Lat. Error | 86.54 | 80.05 | | |
| Min. Lat. Error | -62.21 | -51.12 | | |
| Avg. Abs. Lat. Error | 5.16 | 5.87 | | |
| Stddev. Abs. Lat. Error | 8.84 | 9.54 | | |
| Max. Abs. Lat. Error | 86.54 | 80.05 | | |
| Min. Abs. Lat. Error | 0 | 0 | | |
| Avg. Long. Error | 0.74 | 1.57 | | |
| Stddev. Long. Error | 10.93 | 11.92 | | |
| Max. Long. Error | 77.47 | 52.26 | | |
| Min. Long. Error | -58.65 | -36.95 | | |
| Avg. Abs. Long. Error | 7 | 7.46 | | |
| Stddev. Abs. Long. Error | 8.42 | 9.42 | | |
| Max. Abs. Long. Error | 77.47 | 52.26 | | |
| Min. Abs. Long. Error | 0 | 0.01 | | |
| Avg. Vert. Error | -65.69 | -620.82 | | |
| Stddev. Vert. Error | 2979.91 | 3577.84 | | |
| Max. Vert. Error | 29003 | 16996 | | |
| Min. Vert. Error | -17851 | -16883 | | |
| Avg. Abs. Vert. Error | 1289.48 | 1900.28 | | |
| Stddev. Abs. Vert. Error | 2687.17 | 3093.23 | | |
| Max. Abs. Vert. Error | 29003 | 16996 | | |
| Min. Abs. Vert. Error | 0 | 0 | | |
| Avg. Slant Range Error | 10.26 | 11.18 | | |
| Stddev. Slant Range Error | 10.94 | 12.06 | | |
| Max. Slant Range Error | 87.65 | 80.1 | | |
| Min. Slant Range Error | 0.03 | 0.16 | | |

**Figure A.2- 96 Descriptive Statistics for Horizontal Phase of Flight per Look Ahead Time for Samples at Altitudes Above 18,000 Feet**

### A.2.3.2 Statistical Tests




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 27264 | 0.264519 | 0.833229 | 0.00505 |
| TRN | 5295 | 0.331566 | 0.926179 | 0.01273 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | TRN | STR |
|---|---|---|
| TRN | 0.000000 | 0.067046 |
| STR | -0.06705 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96004

| Abs(Dif)-LSD | TRN | STR |
|---|---|---|
| TRN | -0.03234 | 0.042055 |
| STR | 0.042055 | -0.01425 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 27264 | 0.8332289 | 0.2365059 | 0.1939988 |
| TRN | 5295 | 0.9261793 | 0.3046642 | 0.2557873 |

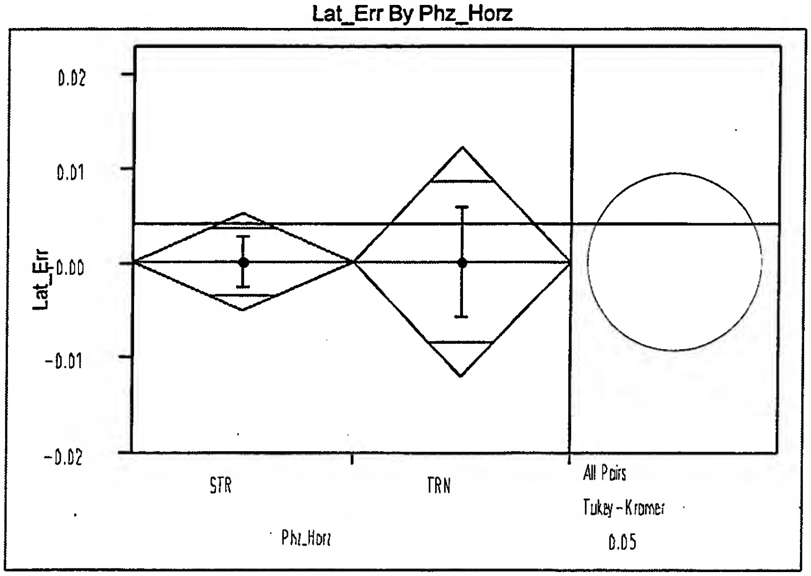
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 0.3673 | 1 | 32557 | 0.5445 |
| Brown-Forsythe | 24.2398 | 1 | 32557 | <.0001 |
| Levene | 31.2597 | 1 | 32557 | <.0001 |
| Bartlett | 103.9422 | 1 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 23.9786 | 1 | 7055.2 | <.0001 |

| t-Test |
|---|
| 4.8968 |

**Figure A.2- 97 Statistical Tests for Horizontal Error and Horizontal Phase of Flight at Look Ahead Time 0 for Samples at All Altitudes**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 27264 | 0.000231 | 0.457736 | 0.00277 |
| TRN | 5295 | 0.001114 | 0.436308 | 0.00600 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | TRN | STR |
|---|---|---|
| TRN | 0.000000 | 0.000884 |
| STR | -0.00088 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96004

| Abs(Dif)-LSD | TRN | STR |
|---|---|---|
| TRN | -0.01731 | -0.01249 |
| STR | -0.01249 | -0.00763 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 27264 | 0.4577364 | 0.1178316 | 0.1178224 |
| TRN | 5295 | 0.4363083 | 0.1693752 | 0.1693221 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 0.0695 | 1 | 32557 | 0.7921 |
| Brown-Forsythe | 61.8537 | 1 | 32557 | <.0001 |
| Levene | 61.9610 | 1 | 32557 | <.0001 |
| Bartlett | 19.9428 | 1 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

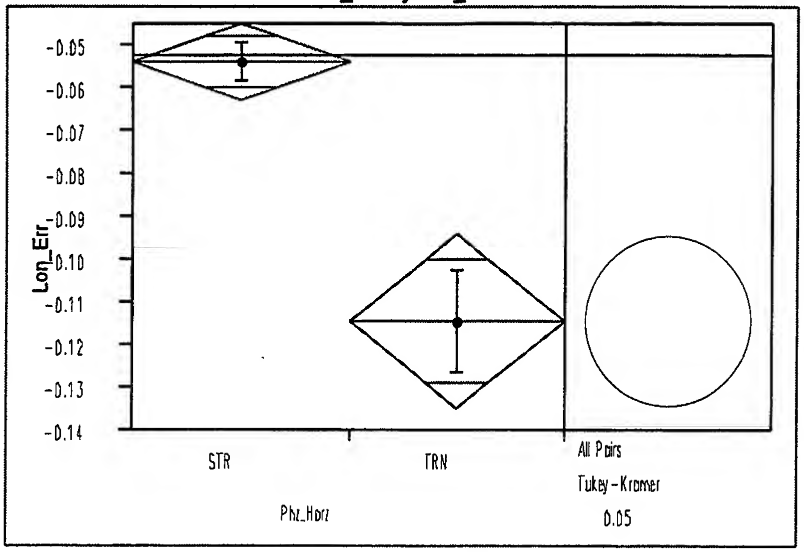
| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 0.0179 | 1 | 7730.6 | 0.8936 |

t-Test

0.1338

**Figure A.2- 98 Statistical Tests for Lateral Error and Horizontal Phase of Flight at Look Ahead Time 0 for Samples at All Altitudes**

Lon_Err By Phz_Horz




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 27264 | -0.0385 | 0.743800 | 0.00450 |
| TRN | 5295 | -0.10702 | 0.875181 | 0.01203 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | STR | TRN |
|---|---|---|
| STR | 0.000000 | 0.068517 |
| TRN | -0.06852 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96004

| Abs(Dif)-LSD | STR | TRN |
|---|---|---|
| STR | -0.01287 | 0.045949 |
| TRN | 0.045949 | -0.02921 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 27264 | 0.7437996 | 0.1995113 | 0.1995111 |
| TRN | 5295 | 0.8751809 | 0.2347585 | 0.2290639 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 0.7503 | 1 | 32557 | 0.3864 |
| Brown-Forsythe | 7.0894 | 1 | 32557 | 0.0078 |
| Levene | 10.0976 | 1 | 32557 | 0.0015 |
| Bartlett | 252.0478 | 1 | ? | <.0001 |

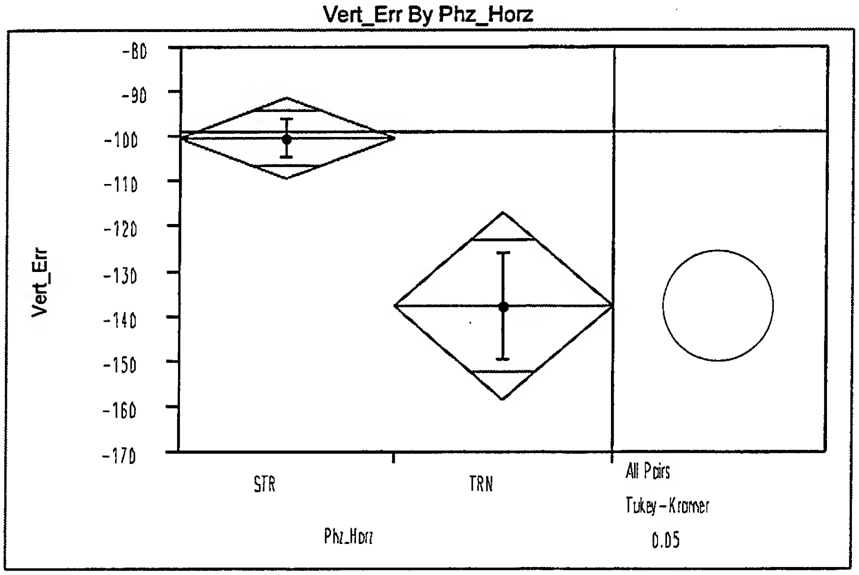
Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 28.4616 | 1 | 6857.2 | <.0001 |

t-Test

5.3349

**Figure A.2- 99 Statistical Tests for Longitudinal Error and Horizontal Phase of Flight at Look Ahead Time 0 for Samples at All Altitudes**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 27264 | -92.649 | 767.552 | 4.649 |
| TRN | 5295 | -130.028 | 887.590 | 12.198 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | STR | TRN |
|---|---|---|
| STR | 0.0000 | 37.3792 |
| TRN | -37.3792 | 0.0000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96004

| Abs(Dif)-LSD | STR | TRN |
|---|---|---|
| STR | -13.2338 | 14.1746 |
| TRN | 14.1746 | -30.0295 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 27264 | 767.5522 | 197.5797 | 149.1224 |
| TRN | 5295 | 887.5899 | 241.5362 | 178.5519 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 1.0469 | 1 | 32557 | 0.3062 |
| Brown-Forsythe | 6.3205 | 1 | 32557 | 0.0119 |
| Levene | 14.7896 | 1 | 32557 | 0.0001 |
| Bartlett | 199.6234 | 1 | ? | <.0001 |

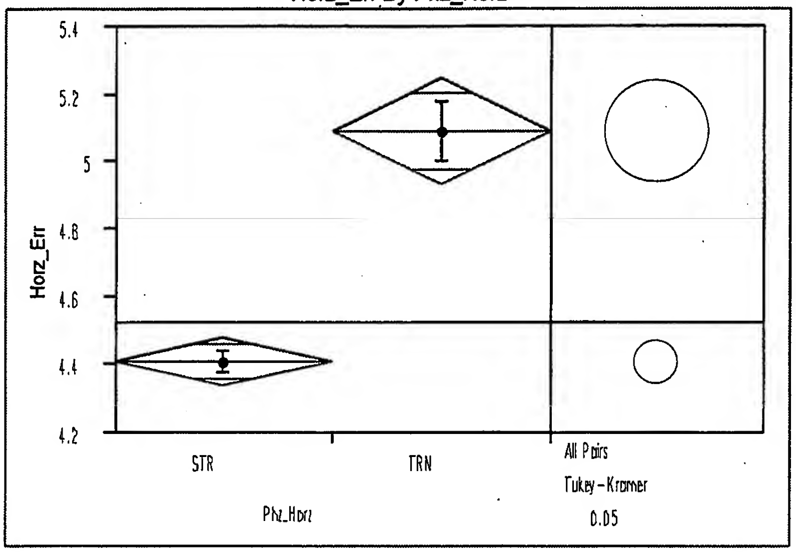
Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 8.1999 | 1 | 6915.1 | 0.0042 |

| t-Test |
|---|
| 2.8635 |

**Figure A.2- 100 Statistical Tests for Vertical Error and Horizontal Phase of Flight at Look Ahead Time 0 for Samples at All Altitudes**

Horz_Err By Phz_Horz




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 18383 | 4.41936 | 4.85142 | 0.03578 |
| TRN | 3496 | 5.09933 | 5.43096 | 0.09185 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | TRN | STR |
|---|---|---|
| TRN | 0.000000 | 0.679975 |
| STR | -0.67998 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96007

| Abs(Dif)-LSD | TRN | STR |
|---|---|---|
| TRN | -0.232 | 0.501009 |
| STR | 0.501009 | -0.10117 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 18383 | 4.851417 | 3.377828 | 3.094611 |
| TRN | 3496 | 5.430962 | 3.812087 | 3.516101 |

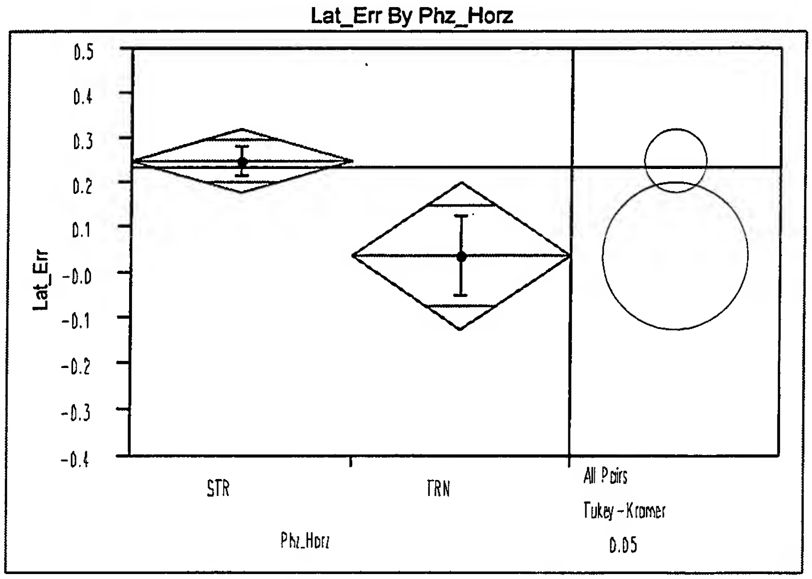
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 11.9422 | 1 | 21877 | 0.0005 |
| Brown-Forsythe | 30.2115 | 1 | 21877 | <.0001 |
| Levene | 44.0381 | 1 | 21877 | <.0001 |
| Bartlett | 78.6677 | 1 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 47.5822 | 1 | 4616 | <.0001 |

t-Test
6.8980

**Figure A.2- 101 Statistical Tests for Horizontal Error and Horizontal Phase of Flight at Look Ahead Time 600 for Samples at All Altitudes**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 18383 | 0.271442 | 4.93684 | 0.03641 |
| TRN | 3496 | 0.050082 | 5.50190 | 0.09305 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | STR | TRN |
|---|---|---|
| STR | 0.000000 | 0.221360 |
| TRN | -0.22136 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96007

| Abs(Dif)-LSD | STR | TRN |
|---|---|---|
| STR | -0.10286 | 0.039398 |
| TRN | 0.039398 | -0.23588 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 18383 | 4.936844 | 2.643731 | 2.595941 |
| TRN | 3496 | 5.501902 | 2.977712 | 2.975884 |

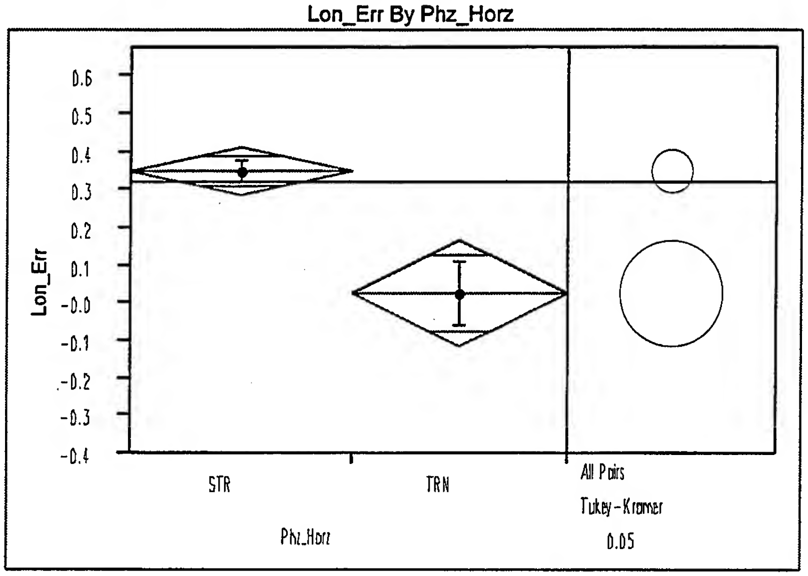
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 12.2004 | 1 | 21877 | 0.0005 |
| Brown-Forsythe | 23.1718 | 1 | 21877 | <.0001 |
| Levene | 18.1775 | 1 | 21877 | <.0001 |
| Bartlett | 72.4041 | 1 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 4.9076 | 1 | 4626.6 | 0.0268 |

t-Test
2.2153

**Figure A.2- 102 Statistical Tests for Lateral Error and Horizontal Phase of Flight at Look Ahead Time 600 for Samples at All Altitudes**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 18383 | 0.349696 | 4.30111 | 0.03172 |
| TRN | 3496 | 0.001907 | 5.02320 | 0.08496 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | STR | TRN |
|---|---|---|
| STR | 0.000000 | 0.347789 |
| TRN | -0.34779 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96007

| Abs(Dif)-LSD | STR | TRN |
|---|---|---|
| STR | -0.09046 | 0.187780 |
| TRN | 0.187780 | -0.20742 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 18383 | 4.301115 | 2.744387 | 2.741431 |
| TRN | 3496 | 5.023198 | 3.238126 | 3.236695 |

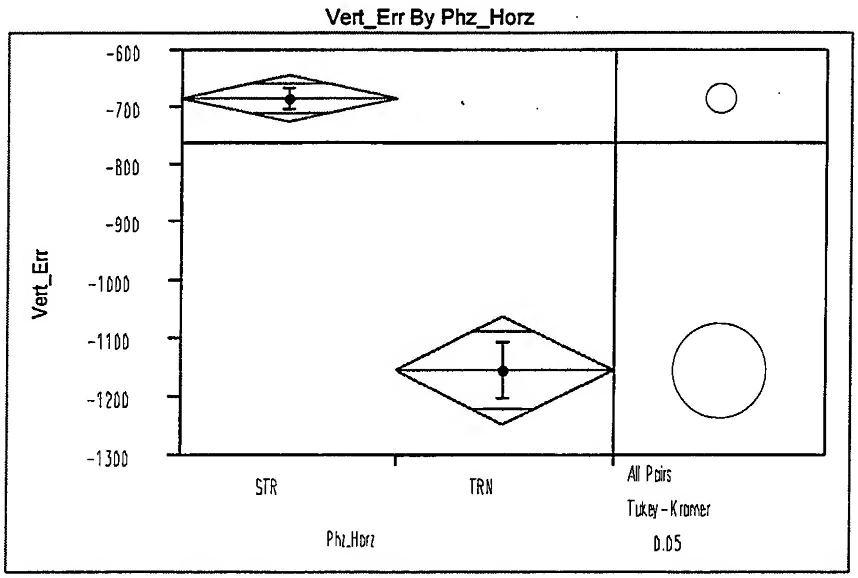
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 24.9127 | 1 | 21877 | <.0001 |
| Brown-Forsythe | 62.1081 | 1 | 21877 | <.0001 |
| Levene | 61.8858 | 1 | 21877 | <.0001 |
| Bartlett | 151.5898 | 1 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 14.7081 | 1 | 4520.9 | 0.0001 |

t-Test
3.8351

**Figure A.2- 103 Statistical Tests for Longitudinal Error and Horizontal Phase of Flight at Look Ahead Time 600 for Samples at All Altitudes**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 18383 | -684.67 | 2796.76 | 20.628 |
| TRN | 3496 | -1151.68 | 3046.70 | 51.528 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | STR | TRN |
|---|---|---|
| STR | 0.000 | 467.004 |
| TRN | -467.004 | 0.000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96007

| Abs(Dif)-LSD | STR | TRN |
|---|---|---|
| STR | -58.025 | 364.360 |
| TRN | 364.360 | -133.058 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 18383 | 2796.759 | 1727.401 | 1437.303 |
| TRN | 3496 | 3046.698 | 2138.179 | 1854.463 |

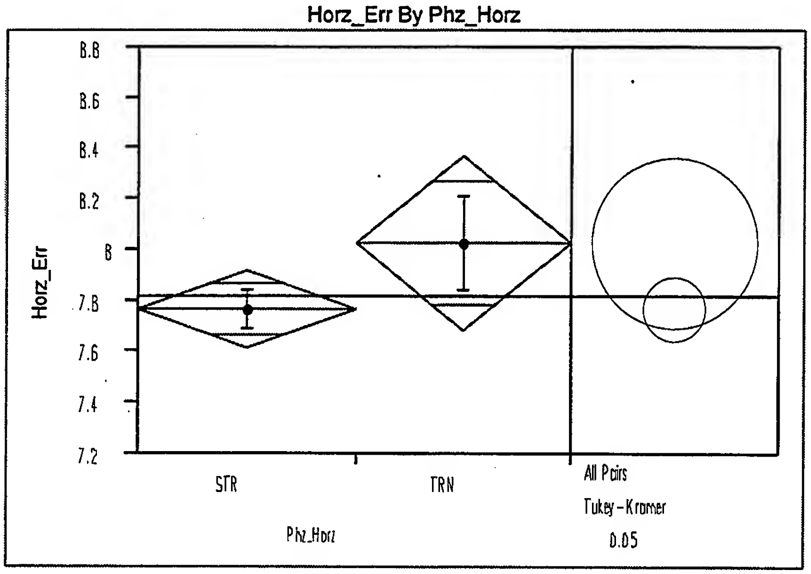
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 8.4916 | 1 | 21877 | 0.0036 |
| Brown-Forsythe | 80.1809 | 1 | 21877 | <.0001 |
| Levene | 102.8909 | 1 | 21877 | <.0001 |
| Bartlett | 44.7184 | 1 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 70.7946 | 1 | 4682.1 | <.0001 |

t-Test
8.4140

**Figure A.2- 104 Statistical Tests for Vertical Error and Horizontal Phase of Flight at Look Ahead Time 600 for Samples at All Altitudes**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 10835 | 7.78408 | 8.05411 | 0.07738 |
| TRN | 2071 | 8.02718 | 8.45143 | 0.18571 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | TRN | STR |
|---|---|---|
| TRN | 0.000000 | 0.243101 |
| STR | -0.2431 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96015

| Abs(Dif)-LSD | TRN | STR |
|---|---|---|
| TRN | -0.49457 | -0.13857 |
| STR | -0.13857 | -0.21622 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 10835 | 8.054112 | 5.778909 | 5.349948 |
| TRN | 2071 | 8.451432 | 6.002259 | 5.569880 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 1.3686 | 1 | 12904 | 0.2421 |
| Brown-Forsythe | 1.8934 | 1 | 12904 | 0.1688 |
| Levene | 2.7022 | 1 | 12904 | 0.1002 |
| Bartlett | 8.2351 | 1 | ? | 0.0041 |

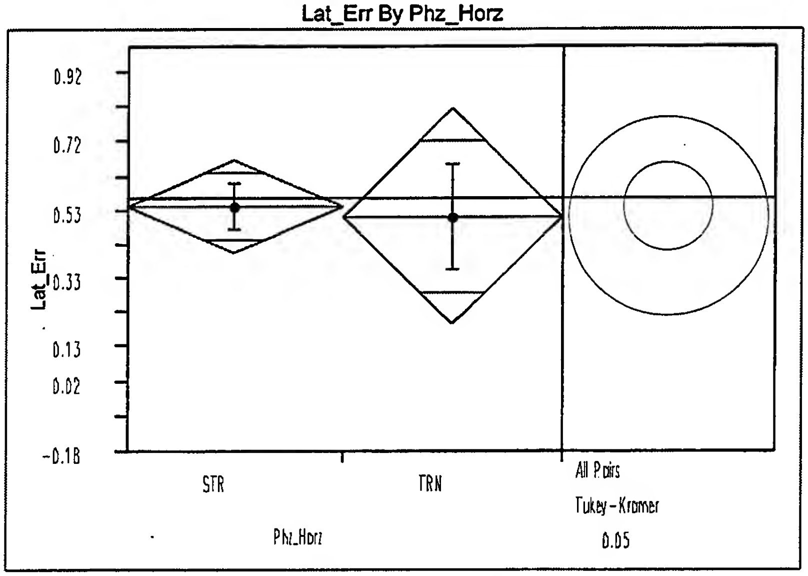
Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 1.4601 | 1 | 2834.7 | 0.2270 |

t-Test

1.2083

**Figure A.2- 105 Statistical Tests for Horizontal Error and Horizontal Phase of Flight at Look Ahead Time 1200 for Samples at All Altitudes**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 10835 | 0.571675 | 7.52091 | 0.07225 |
| TRN | 2071 | 0.511069 | 7.13722 | 0.15683 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | STR | TRN |
|---|---|---|
| STR | 0.000000 | 0.060605 |
| TRN | -0.06061 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96015

| Abs(Dif)-LSD | STR | TRN |
|---|---|---|
| STR | -0.19869 | -0.29011 |
| TRN | -0.29011 | -0.45446 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 10835 | 7.520910 | 4.054863 | 3.925750 |
| TRN | 2071 | 7.137216 | 3.953829 | 3.874962 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 1.2475 | 1 | 12904 | 0.2641 |
| Brown-Forsythe | 0.1104 | 1 | 12904 | 0.7397 |
| Levene | 0.4511 | 1 | 12904 | 0.5018 |
| Bartlett | 9.3052 | 1 | ? | 0.0023 |

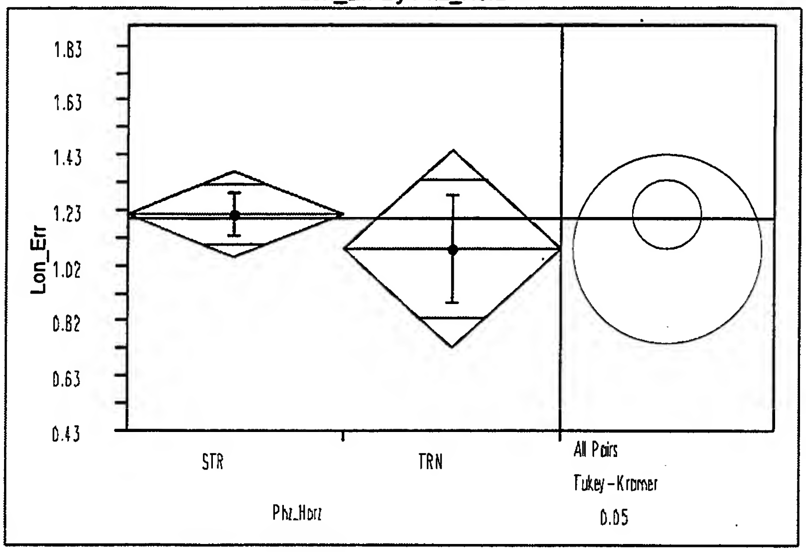
Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 0.1232 | 1 | 3016 | 0.7256 |

t-Test
0.3510

**Figure A.2- 106 Statistical Tests for Lateral Error and Horizontal Phase of Flight at Look Ahead Time 1200 for Samples at All Altitudes**

Lon_Err By Phz_Horz




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 10835 | 1.21619 | 8.19122 | 0.07869 |
| TRN | 2071 | 1.10775 | 9.13590 | 0.20075 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | STR | TRN |
|---|---|---|
| STR | 0.000000 | 0.108443 |
| TRN | -0.10844 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96015

| Abs(Dif)-LSD | STR | TRN |
|---|---|---|
| STR | -0.22237 | -0.28408 |
| TRN | -0.28408 | -0.50863 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 10835 | 8.191218 | 5.376988 | 5.352639 |
| TRN | 2071 | 9.135898 | 5.759456 | 5.745554 |

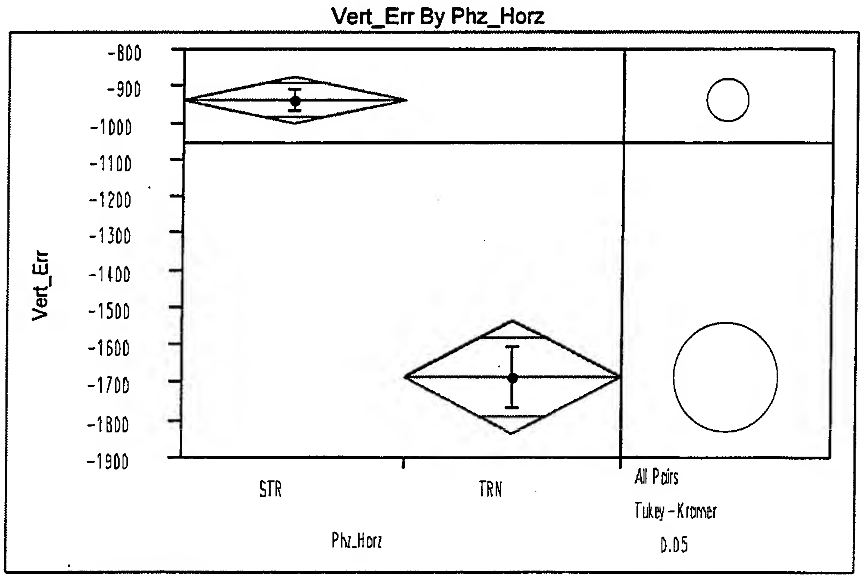
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 8.8611 | 1 | 12904 | 0.0029 |
| Brown-Forsythe | 6.6045 | 1 | 12904 | 0.0102 |
| Levene | 6.3391 | 1 | 12904 | 0.0118 |
| Bartlett | 43.4774 | 1 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 0.2529 | 1 | 2742.6 | 0.6151 |

t-Test
0.5029

**Figure A.2- 107 Statistical Tests for Longitudinal Error and Horizontal Phase of Flight at Look Ahead Time 1200 for Samples at All Altitudes**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 10835 | -934.42 | 3509.02 | 33.711 |
| TRN | 2071 | -1681.97 | 3884.51 | 85.358 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | STR | TRN |
|---|---|---|
| STR | 0.000 | 747.554 |
| TRN | -747.554 | 0.000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96015

| Abs(Dif)-LSD | STR | TRN |
|---|---|---|
| STR | -95.124 | 579.642 |
| TRN | 579.642 | -217.578 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 10835 | 3509.019 | 2212.443 | 1840.122 |
| TRN | 2071 | 3884.508 | 2788.978 | 2480.770 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 7.6384 | 1 | 12904 | 0.0057 |
| Brown-Forsythe | 70.6209 | 1 | 12904 | <.0001 |
| Levene | 78.0962 | 1 | 12904 | <.0001 |
| Bartlett | 37.5909 | 1 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

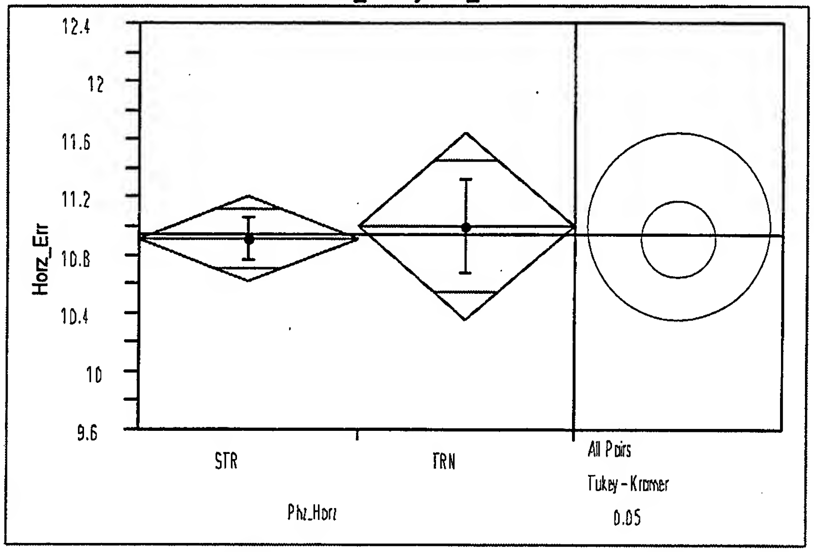
| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 66.3506 | 1 | 2753.3 | <.0001 |

t-Test

8.1456

**Figure A.2- 108 Statistical Tests for Vertical Error and Horizontal Phase of Flight at Look Ahead Time 1200 for Samples at All Altitudes**

Horz_Err By Phz_Horz




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 5533 | 10.9251 | 11.2512 | 0.15126 |
| TRN | 1119 | 11.0378 | 11.0722 | 0.33099 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | TRN | STR |
|---|---|---|
| TRN | 0.000000 | 0.112691 |
| STR | -0.11269 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96032

| Abs(Dif)-LSD | TRN | STR |
|---|---|---|
| TRN | -0.92997 | -0.60834 |
| STR | -0.60834 | -0.41822 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 5533 | 11.25121 | 8.199874 | 7.558824 |
| TRN | 1119 | 11.07216 | 8.289999 | 7.573824 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 0.1083 | 1 | 6650 | 0.7421 |
| Brown-Forsythe | 0.0025 | 1 | 6650 | 0.9603 |
| Levene | 0.1294 | 1 | 6650 | 0.7190 |
| Bartlett | 0.4752 | 1 | ? | 0.4906 |

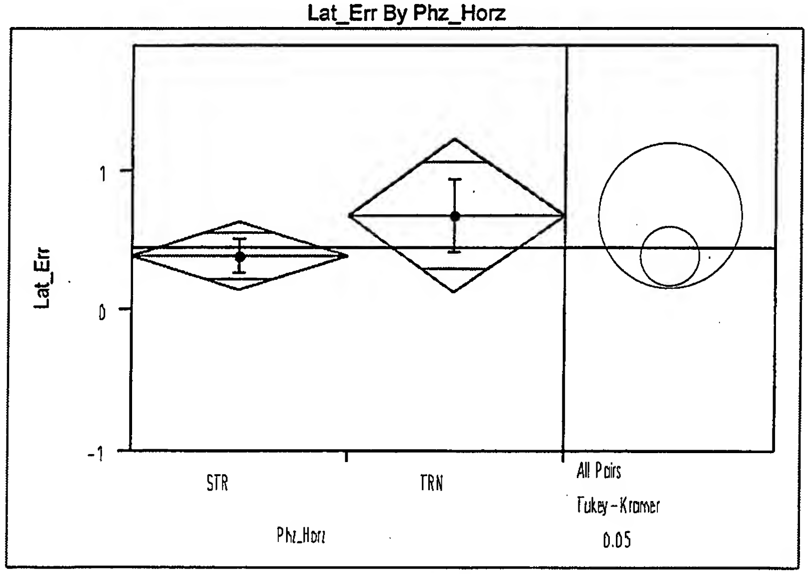
Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 0.0959 | 1 | 1619.4 | 0.7569 |

t-Test
0.3097

**Figure A.2- 109 Statistical Tests for Horizontal Error and Horizontal Phase of Flight at Look Ahead Time 1800 for Samples at All Altitudes**

Lat_Err By Phz_Horz




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 5533 | 0.402110 | 9.50760 | 0.12782 |
| TRN | 1119 | 0.716969 | 8.81856 | 0.26362 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | TRN | STR |
|---|---|---|
| TRN | 0.000000 | 0.314859 |
| STR | -0.31486 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96032

| Abs(Dif)-LSD | TRN | STR |
|---|---|---|
| TRN | -0.77864 | -0.28884 |
| STR | -0.28884 | -0.35016 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 5533 | 9.507599 | 4.986602 | 4.918904 |
| TRN | 1119 | 8.818562 | 4.737475 | 4.624016 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 1.1621 | 1 | 6650 | 0.2811 |
| Brown-Forsythe | 1.2499 | 1 | 6650 | 0.2636 |
| Levene | 0.9054 | 1 | 6650 | 0.3414 |
| Bartlett | 10.1778 | 1 | ? | 0.0014 |

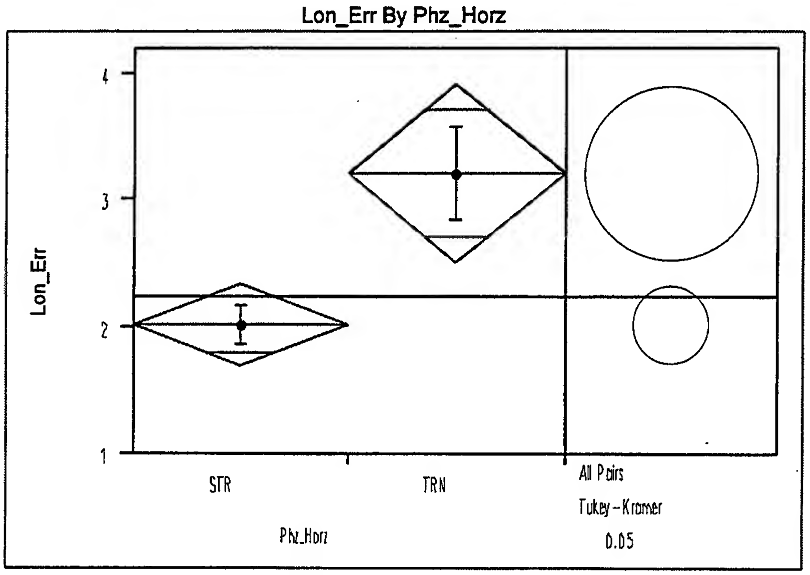
Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 1.1550 | 1 | 1686.6 | 0.2827 |

t-Test

1.0747

**Figure A.2- 110 Statistical Tests for Lateral Error and Horizontal Phase of Flight at Look Ahead Time 1800 for Samples at All Altitudes**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 5533 | 2.23391 | 12.2647 | 0.16488 |
| TRN | 1119 | 3.41451 | 12.4332 | 0.37168 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | TRN | STR |
|---|---|---|
| TRN | 0.00000 | 1.18061 |
| STR | -1.18061 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96032

| Abs(Dif)-LSD | TRN | STR |
|---|---|---|
| TRN | -1.01880 | 0.39071 |
| STR | 0.39071 | -0.45817 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 5533 | 12.26465 | 8.110204 | 8.010440 |
| TRN | 1119 | 12.43317 | 8.499094 | 8.308092 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 0.0995 | 1 | 6650 | 0.7525 |
| Brown-Forsythe | 0.9360 | 1 | 6650 | 0.3333 |
| Levene | 1.6710 | 1 | 6650 | 0.1962 |
| Bartlett | 0.3484 | 1 | ? | 0.5550 |

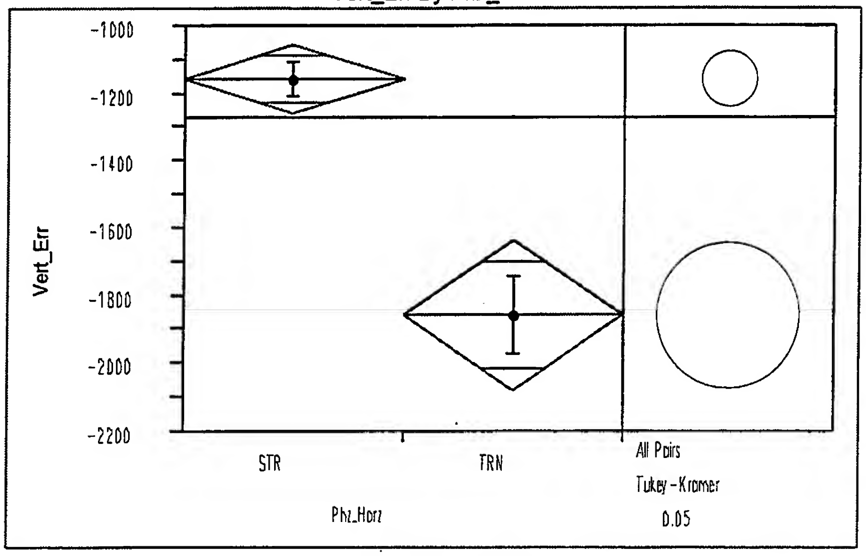
Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 8.4306 | 1 | 1588.9 | 0.0037 |

t-Test
2.9035

**Figure A.2- 111 Statistical Tests for Longitudinal Error and Horizontal Phase of Flight at Look Ahead Time 1800 for Samples at All Altitudes**

Vert_Err By Phz_Horz




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 5533 | -1148.82 | 3830.91 | 51.50 |
| TRN | 1119 | -1854.55 | 4008.78 | 119.84 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | STR | TRN |
|---|---|---|
| STR | 0.000 | 705.728 |
| TRN | -705.728 | 0.000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96032

| Abs(Dif)-LSD | STR | TRN |
|---|---|---|
| STR | -143.915 | 457.614 |
| TRN | 457.614 | -320.015 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 5533 | 3830.906 | 2523.343 | 2077.579 |
| TRN | 1119 | 4008.777 | 3004.115 | 2596.993 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 0.9234 | 1 | 6650 | 0.3366 |
| Brown-Forsythe | 21.1780 | 1 | 6650 | <.0001 |
| Levene | 26.5802 | 1 | 6650 | <.0001 |
| Bartlett | 3.9075 | 1 | ? | 0.0481 |

Welch Anova testing Means Equal, allowing Std's Not Equal

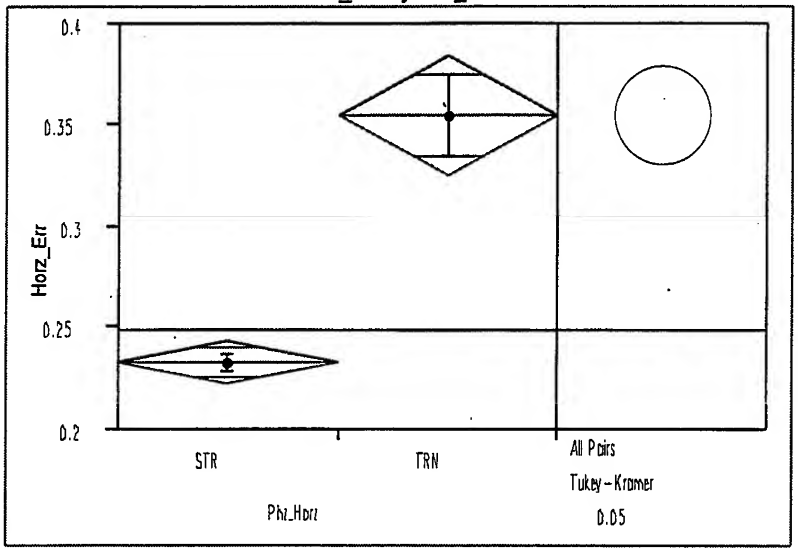
| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 29.2735 | 1 | 1558.4 | <.0001 |

t-Test

5.4105

**Figure A.2- 112 Statistical Tests for Vertical Error and Horizontal Phase of Flight at Look Ahead Time 1800 for Samples at All Altitudes**

Horz_Err By Phz_Horz




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 18660 | 0.234469 | 0.71145 | 0.00521 |
| TRN | 2505 | 0.357088 | 1.00994 | 0.02018 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | TRN | STR |
|---|---|---|
| TRN | 0.000000 | 0.122619 |
| STR | -0.12262 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96008

| Abs(Dif)-LSD | TRN | STR |
|---|---|---|
| TRN | -0.0417 | 0.091214 |
| STR | 0.091214 | -0.01528 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 18660 | 0.711449 | 0.1940809 | 0.1629565 |
| TRN | 2505 | 1.009945 | 0.3193173 | 0.2706653 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 1.4391 | 1 | 21163 | 0.2303 |
| Brown-Forsythe | 46.7234 | 1 | 21163 | <.0001 |
| Levene | 66.3991 | 1 | 21163 | <.0001 |
| Bartlett | 645.8713 | 1 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

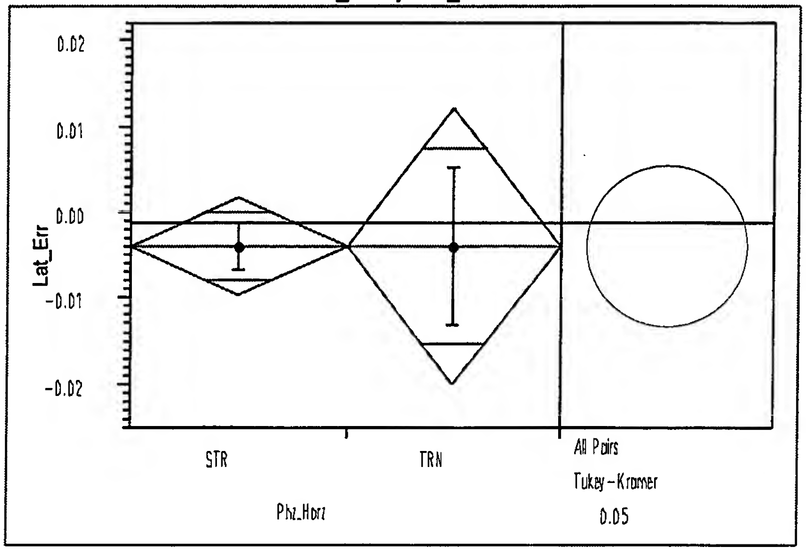
| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 34.6191 | 1 | 2847 | <.0001 |

t-Test

5.8838

**Figure A.2- 113 Statistical Tests for Horizontal Error and Horizontal Phase of Flight at Look Ahead Time 0 for Samples at Altitudes Above 18,000 Feet**

Lat_Err By Phz_Horz




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 18660 | -0.00106 | 0.403764 | 0.00296 |
| TRN | 2505 | -0.0024 | 0.465094 | 0.00929 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | STR | TRN |
|---|---|---|
| STR | 0.000000 | 0.001338 |
| TRN | -0.00134 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96008

| Abs(Dif)-LSD | STR | TRN |
|---|---|---|
| STR | -0.00835 | -0.01583 |
| TRN | -0.01583 | -0.02279 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 18660 | 0.4037643 | 0.0987145 | 0.0987052 |
| TRN | 2505 | 0.4650941 | 0.1861093 | 0.1859884 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 0.2594 | 1 | 21163 | 0.6105 |
| Brown-Forsythe | 107.4089 | 1 | 21163 | <.0001 |
| Levene | 107.6896 | 1 | 21163 | <.0001 |
| Bartlett | 94.8468 | 1 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

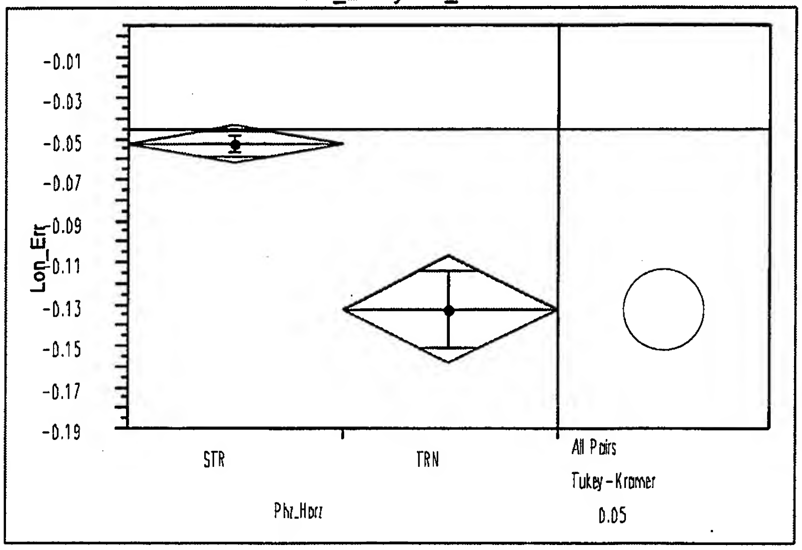
| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 0.0188 | 1 | 3032.1 | 0.8909 |

t-Test

0.1372

**Figure A.2- 114 Statistical Tests for Lateral Error and Horizontal Phase of Flight at Look Ahead Time 0 for Samples at Altitudes Above 18,000 Feet**

Lon_Err By Phz_Horz




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 18660 | -0.03411 | 0.630039 | 0.00461 |
| TRN | 2505 | -0.12295 | 0.957136 | 0.01912 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | STR | TRN |
|---|---|---|
| STR | 0.000000 | 0.088839 |
| TRN | -0.08884 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96008

| Abs(Dif)-LSD | STR | TRN |
|---|---|---|
| STR | -0.01374 | 0.060601 |
| TRN | 0.060601 | -0.0375 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 18660 | 0.6300389 | 0.1795647 | 0.1794284 |
| TRN | 2505 | 0.9571364 | 0.2469901 | 0.2423914 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 1.7649 | 1 | 21163 | 0.1840 |
| Brown-Forsythe | 20.6874 | 1 | 21163 | <.0001 |
| Levene | 23.7514 | 1 | 21163 | <.0001 |
| Bartlett | 950.6784 | 1 | ? | <.0001 |

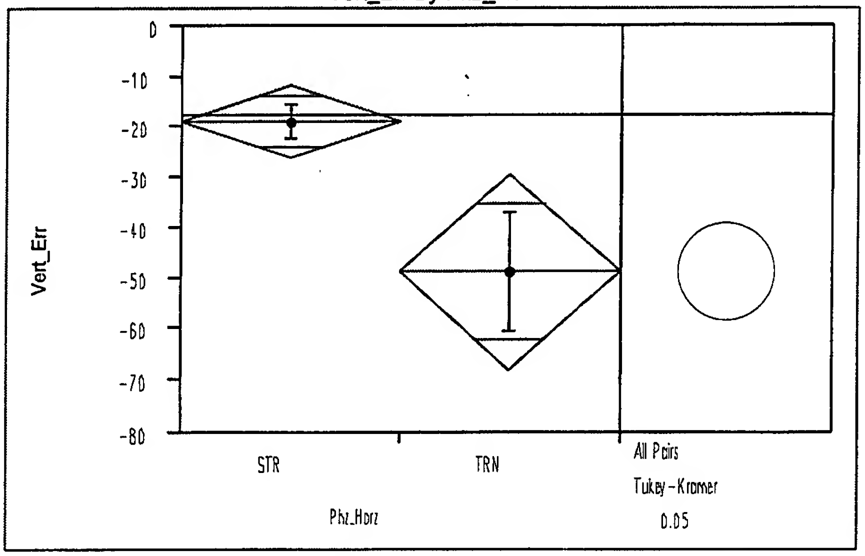
Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 20.3944 | 1 | 2802.5 | <.0001 |

t-Test
4.5160

**Figure A.2- 115 Statistical Tests for Longitudinal Error and Horizontal Phase of Flight at Look Ahead Time 0 for Samples at Altitudes Above 18,000 Feet**

Vert_Err By Phz_Horz




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 18660 | -13.9225 | 485.830 | 3.557 |
| TRN | 2505 | -44.4052 | 595.086 | 11.890 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | STR | TRN |
|---|---|---|
| STR | 0.0000 | 30.4828 |
| TRN | -30.4828 | 0.0000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96008

| Abs(Dif)-LSD | STR | TRN |
|---|---|---|
| STR | -10.1463 | 9.6284 |
| TRN | 9.6284 | -27.6922 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 18660 | 485.8298 | 78.6304 | 69.61522 |
| TRN | 2505 | 595.0861 | 121.1243 | 93.71964 |

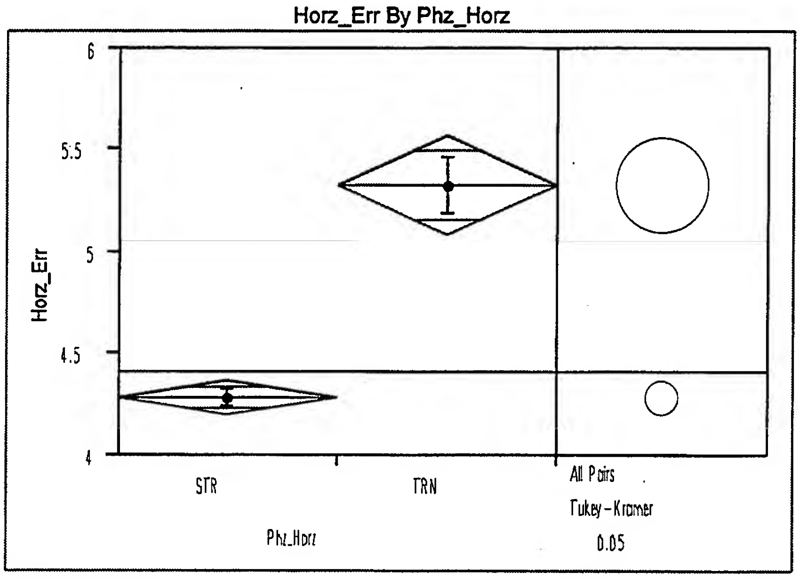
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 0.7024 | 1 | 21163 | 0.4020 |
| Brown-Forsythe | 5.2355 | 1 | 21163 | 0.0221 |
| Levene | 16.4239 | 1 | 21163 | <.0001 |
| Bartlett | 201.2929 | 1 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 6.0331 | 1 | 2969 | 0.0141 |

t-Test
2.4562

**Figure A.2- 116 Statistical Tests for Vertical Error and Horizontal Phase of Flight at Look Ahead Time 0 for Samples at Altitudes Above 18,000 Feet**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 13124 | 4.29516 | 5.04140 | 0.04401 |
| TRN | 1657 | 5.34666 | 5.91720 | 0.14536 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | TRN | STR |
|---|---|---|
| TRN | 0.00000 | 1.05149 |
| STR | -1.05149 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96013

| Abs(Dif)-LSD | TRN | STR |
|---|---|---|
| TRN | -0.3505 | 0.788471 |
| STR | 0.788471 | -0.12454 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 13124 | 5.041404 | 3.423732 | 3.080865 |
| TRN | 1657 | 5.917200 | 4.169448 | 3.792364 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 13.5501 | 1 | 14779 | 0.0002 |
| Brown-Forsythe | 37.9241 | 1 | 14779 | <.0001 |
| Levene | 57.8901 | 1 | 14779 | <.0001 |
| Bartlett | 81.9421 | 1 | ? | <.0001 |

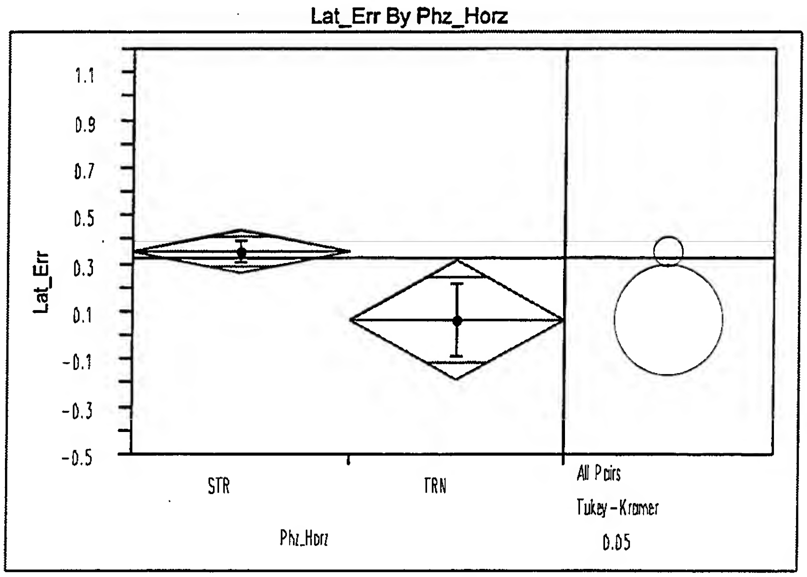
Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 47.9314 | 1 | 1971.4 | <.0001 |

t-Test

6.9232

**Figure A.2- 117 Statistical Tests for Horizontal Error and Horizontal Phase of Flight at Look Ahead Time 600 for Samples at Altitudes Above 18,000 Feet**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 13124 | 0.361254 | 5.21221 | 0.04550 |
| TRN | 1657 | 0.068356 | 6.43539 | 0.15809 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | STR | TRN |
|---|---|---|
| STR | 0.000000 | 0.292898 |
| TRN | -0.2929 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96013

| Abs(Dif)-LSD | STR | TRN |
|---|---|---|
| STR | -0.12977 | 0.018828 |
| TRN | 0.018828 | -0.36522 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 13124 | 5.212211 | 2.717162 | 2.630696 |
| TRN | 1657 | 6.435389 | 3.473404 | 3.469688 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 27.5258 | 1 | 14779 | <.0001 |
| Brown-Forsythe | 48.4269 | 1 | 14779 | <.0001 |
| Levene | 40.3462 | 1 | 14779 | <.0001 |
| Bartlett | 145.6606 | 1 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

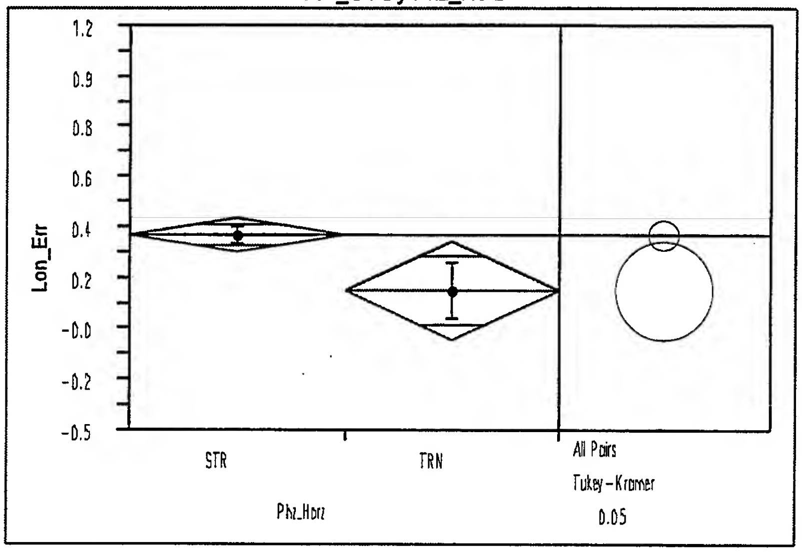
| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 3.1699 | 1 | 1940 | 0.0752 |

t-Test

1.7804

**Figure A.2- 118 Statistical Tests for Lateral Error and Horizontal Phase of Flight at Look Ahead Time 600 for Samples at Altitudes Above 18,000 Feet**

Lon_Err By Phz_Horz




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 13124 | 0.343574 | 4.05584 | 0.03540 |
| TRN | 1657 | 0.104021 | 4.71036 | 0.11572 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | STR | TRN |
|---|---|---|
| STR | 0.000000 | 0.239553 |
| TRN | -0.23955 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96013

| Abs(Dif)-LSD | STR | TRN |
|---|---|---|
| STR | -0.10004 | 0.028278 |
| TRN | 0.028278 | -0.28154 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 13124 | 4.055844 | 2.536440 | 2.530586 |
| TRN | 1657 | 4.710364 | 3.074113 | 3.073069 |

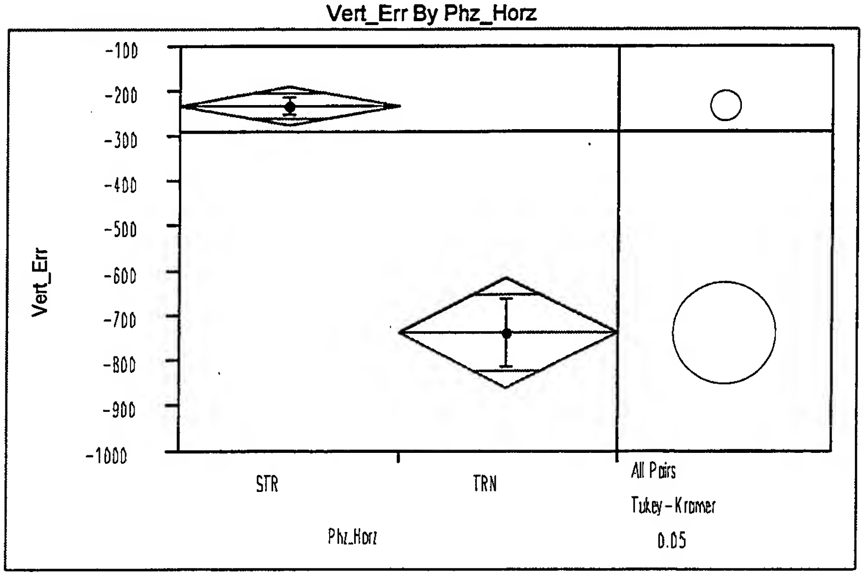
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 11.0260 | 1 | 14779 | 0.0009 |
| Brown-Forsythe | 41.7386 | 1 | 14779 | <.0001 |
| Levene | 41.2130 | 1 | 14779 | <.0001 |
| Bartlett | 71.0945 | 1 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 3.9188 | 1 | 1978.4 | 0.0479 |

t-Test
1.9796

**Figure A.2- 119 Statistical Tests for Longitudinal Error and Horizontal Phase of Flight at Look Ahead Time 600 for Samples at Altitudes Above 18,000 Feet**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 13124 | -228.206 | 2515.82 | 21.961 |
| TRN | 1657 | -739.485 | 3128.62 | 76.859 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | STR | TRN |
|---|---|---|
| STR | 0.000 | 511.279 |
| TRN | -511.279 | 0.000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96013

| Abs(Dif)-LSD | STR | TRN |
|---|---|---|
| STR | -62.712 | 378.837 |
| TRN | 378.837 | -176.491 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 13124 | 2515.824 | 1238.933 | 1107.942 |
| TRN | 1657 | 3128.625 | 2023.243 | 1743.558 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 24.2333 | 1 | 14779 | <.0001 |
| Brown-Forsythe | 110.2038 | 1 | 14779 | <.0001 |
| Levene | 184.8905 | 1 | 14779 | <.0001 |
| Bartlett | 156.3317 | 1 | ? | <.0001 |

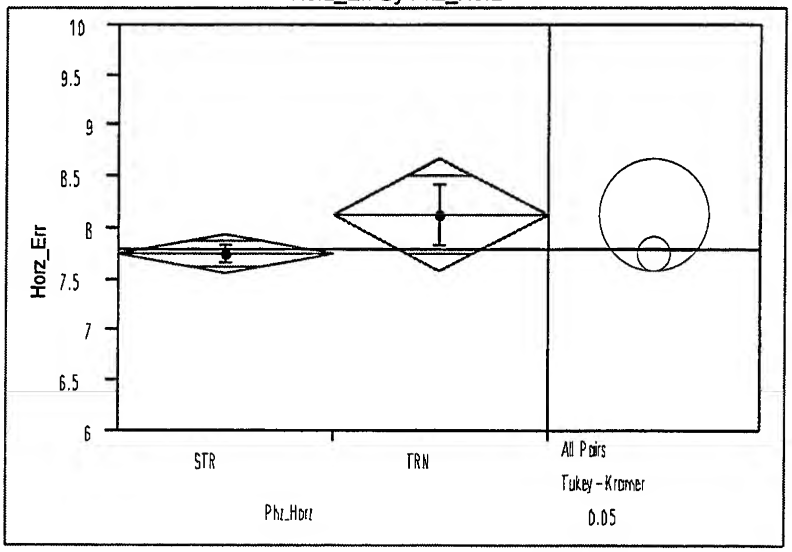
Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 40.9118 | 1 | 1935.8 | <.0001 |

t-Test
6.3962

**Figure A.2- 120 Statistical Tests for Vertical Error and Horizontal Phase of Flight at Look Ahead Time 600 for Samples at Altitudes Above 18,000 Feet**

Horz_Err By Phz_Horz




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 7275 | 7.75291 | 8.35611 | 0.09797 |
| TRN | 899 | 8.12008 | 9.02906 | 0.30114 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | TRN | STR |
|---|---|---|
| TRN | 0.000000 | 0.367168 |
| STR | -0.36717 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96026

| Abs(Dif)-LSD | TRN | STR |
|---|---|---|
| TRN | -0.77968 | -0.21722 |
| STR | -0.21722 | -0.27408 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 7275 | 8.356110 | 5.935296 | 5.441148 |
| TRN | 899 | 9.029061 | 6.335328 | 5.798658 |

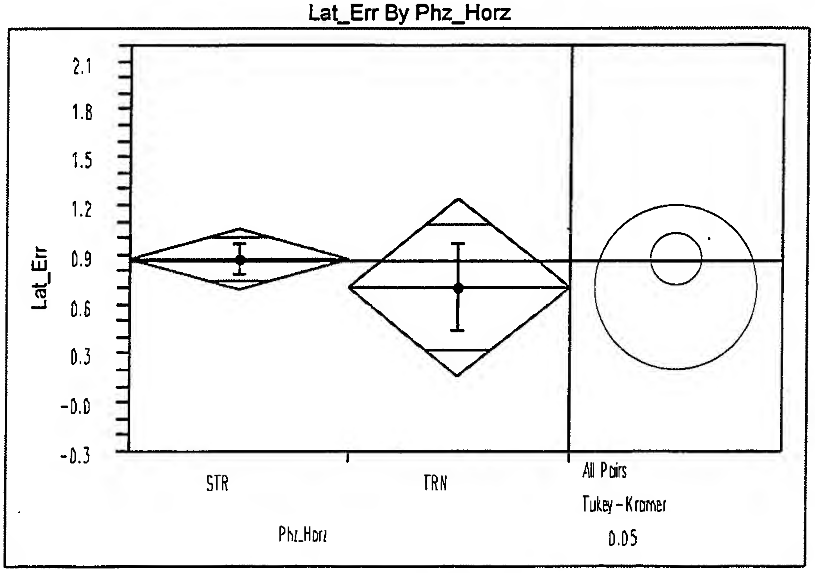
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 1.9409 | 1 | 8172 | 0.1636 |
| Brown-Forsythe | 2.0633 | 1 | 8172 | 0.1509 |
| Levene | 3.6237 | 1 | 8172 | 0.0570 |
| Bartlett | 9.9813 | 1 | ? | 0.0016 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 1.3443 | 1 | 1096.6 | 0.2465 |
| t-Test | | | |
| 1.1595 | | | |

**Figure A.2- 121 Statistical Tests for Horizontal Error and Horizontal Phase of Flight at Look Ahead Time 1200 for Samples at Altitudes Above 18,000 Feet**

Lat_Err By Phz_Horz




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 7275 | 0.883040 | 8.26596 | 0.09691 |
| TRN | 899 | 0.707953 | 8.16178 | 0.27221 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | STR | TRN |
|---|---|---|
| STR | 0.000000 | 0.175086 |
| TRN | -0.17509 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96026

| Abs(Dif)-LSD | STR | TRN |
|---|---|---|
| STR | -0.26829 | -0.39696 |
| TRN | -0.39696 | -0.76321 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 7275 | 8.265958 | 4.502071 | 4.253076 |
| TRN | 899 | 8.161776 | 4.561810 | 4.429300 |

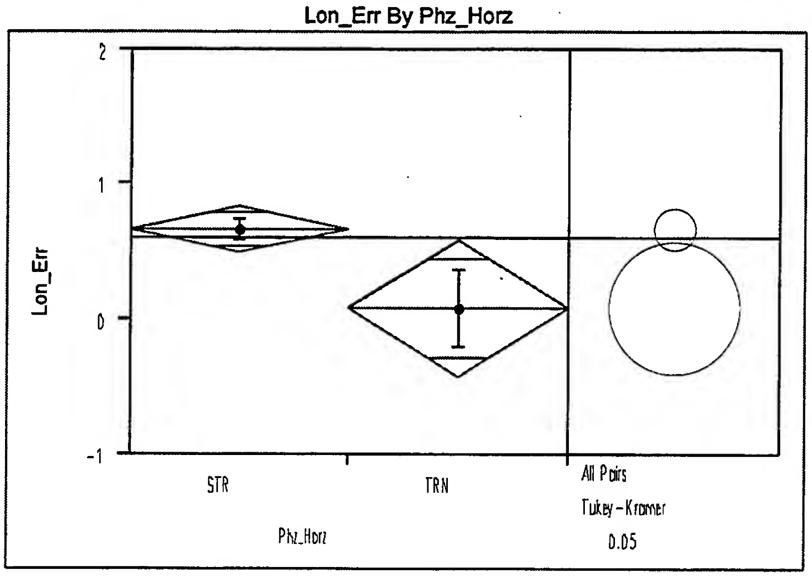
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 0.0381 | 1 | 8172 | 0.8452 |
| Brown-Forsythe | 0.4910 | 1 | 8172 | 0.4835 |
| Levene | 0.0597 | 1 | 8172 | 0.8069 |
| Bartlett | 0.2554 | 1 | ? | 0.6133 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 0.3672 | 1 | 1137.8 | 0.5447 |

t-Test
0.6059

**Figure A.2- 122 Statistical Tests for Lateral Error and Horizontal Phase of Flight at Look Ahead Time 1200 for Samples at Altitudes Above 18,000 Feet**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 7275 | 0.771716 | 7.76137 | 0.09100 |
| TRN | 899 | 0.207019 | 8.96514 | 0.29900 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | STR | TRN |
|---|---|---|
| STR | 0.000000 | 0.564697 |
| TRN | -0.5647 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96026

| Abs(Dif)-LSD | STR | TRN |
|---|---|---|
| STR | -0.25685 | 0.017044 |
| TRN | 0.017044 | -0.73067 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 7275 | 7.761372 | 5.020612 | 5.006082 |
| TRN | 899 | 8.965141 | 5.380877 | 5.367271 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 7.4284 | 1 | 8172 | 0.0064 |
| Brown-Forsythe | 2.8110 | 1 | 8172 | 0.0937 |
| Levene | 2.8199 | 1 | 8172 | 0.0931 |
| Bartlett | 35.8064 | 1 | ? | <.0001 |

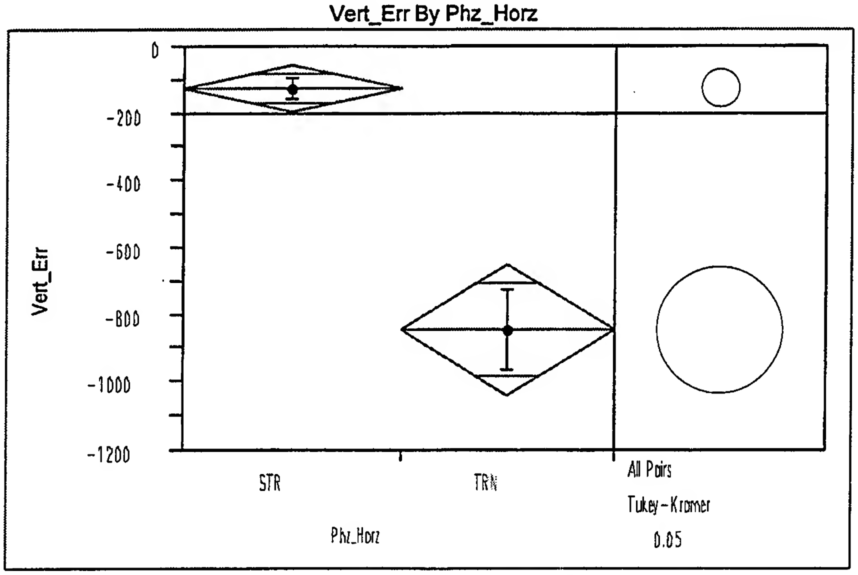
Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 3.2644 | 1 | 1070.9 | 0.0711 |

| t-Test |
|---|
| 1.8068 |

**Figure A.2- 123 Statistical Tests for Longitudinal Error and Horizontal Phase of Flight at Look Ahead Time 1200 for Samples at Altitudes Above 18,000 Feet**

Vert_Err By Phz_Horz




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 7275 | -123.003 | 2955.87 | 34.66 |
| TRN | 899 | -837.674 | 3769.17 | 125.71 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | STR | TRN |
|---|---|---|
| STR | 0.000 | 714.671 |
| TRN | -714.671 | 0.000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96026

| Abs(Dif)-LSD | STR | TRN |
|---|---|---|
| STR | -99.321 | 502.901 |
| TRN | 502.901 | -282.540 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 7275 | 2955.871 | 1329.427 | 1257.581 |
| TRN | 899 | 3769.167 | 2394.261 | 2063.472 |

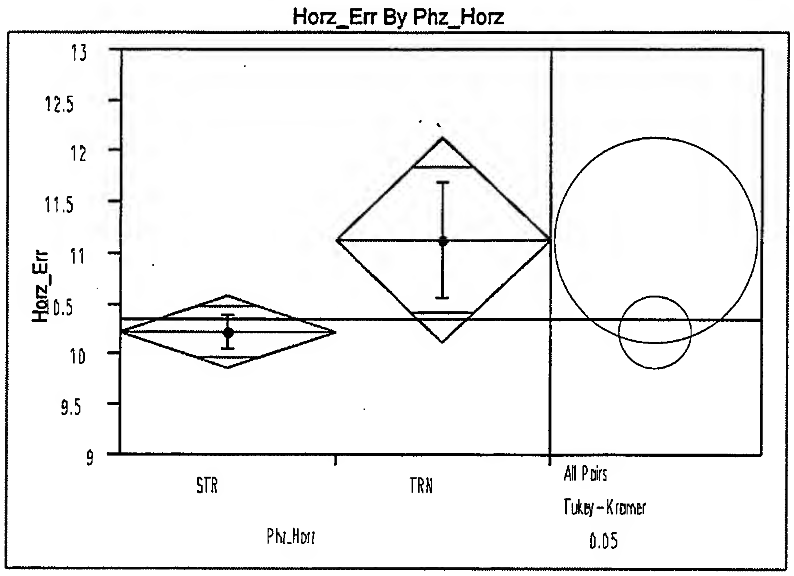
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 15.8051 | 1 | 8172 | <.0001 |
| Brown-Forsythe | 68.8047 | 1 | 8172 | <.0001 |
| Levene | 127.1680 | 1 | 8172 | <.0001 |
| Bartlett | 107.0770 | 1 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 30.0379 | 1 | 1038.9 | <.0001 |

| t-Test |
|---|
| 5.4807 |

**Figure A.2- 124 Statistical Tests for Vertical Error and Horizontal Phase of Flight at Look Ahead Time 1200 for Samples at Altitudes Above 18,000 Feet**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 3466 | 10.2454 | 10.9529 | 0.18604 |
| TRN | 446 | 11.1468 | 12.0732 | 0.57168 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | TRN | STR |
|---|---|---|
| TRN | 0.000000 | 0.901409 |
| STR | -0.90141 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96057

| Abs(Dif)-LSD | TRN | STR |
|---|---|---|
| TRN | -1.45550 | -0.19200 |
| STR | -0.19200 | -0.52211 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 3466 | 10.95292 | 7.759011 | 7.125747 |
| TRN | 446 | 12.07322 | 8.742910 | 7.778772 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 1.8495 | 1 | 3910 | 0.1739 |
| Brown-Forsythe | 1.9751 | 1 | 3910 | 0.1600 |
| Levene | 6.2898 | 1 | 3910 | 0.0122 |
| Bartlett | 7.8580 | 1 | ? | 0.0051 |

Welch Anova testing Means Equal, allowing Std's Not Equal

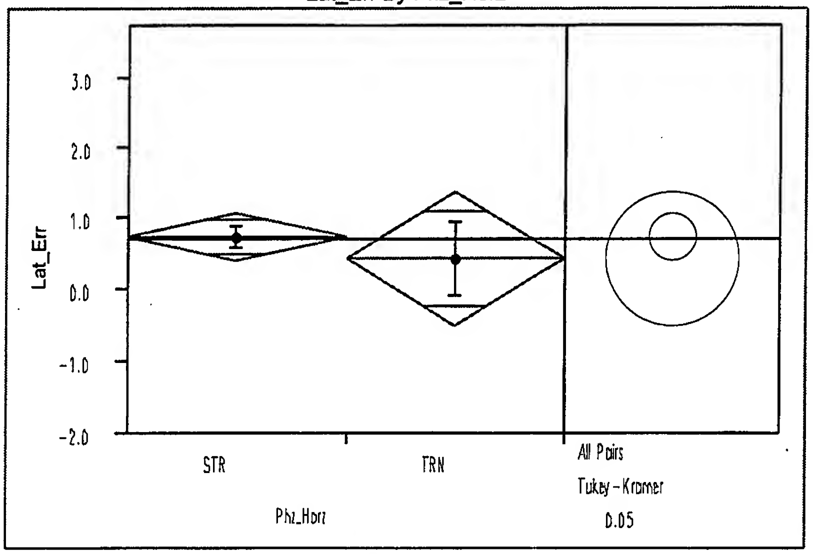
| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 2.2481 | 1 | 543.46 | 0.1344 |

t-Test

1.4994

**Figure A.2- 125 Statistical Tests for Horizontal Error and Horizontal Phase of Flight at Look Ahead Time 1800 for Samples at Altitudes Above 18,000 Feet**

Lat_Err By Phz_Horz




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 3466 | 0.739511 | 10.2167 | 0.17354 |
| TRN | 446 | 0.463890 | 11.2007 | 0.53037 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | STR | TRN |
|---|---|---|
| STR | 0.000000 | 0.275622 |
| TRN | -0.27562 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96057

| Abs(Dif)-LSD | STR | TRN |
|---|---|---|
| STR | -0.48666 | -0.74355 |
| TRN | -0.74355 | -1.35667 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 3466 | 10.21674 | 5.356596 | 5.161818 |
| TRN | 446 | 11.20066 | 5.935987 | 5.873975 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 0.9586 | 1 | 3910 | 0.3276 |
| Brown-Forsythe | 2.5132 | 1 | 3910 | 0.1130 |
| Levene | 1.7155 | 1 | 3910 | 0.1904 |
| Bartlett | 6.9853 | 1 | ? | 0.0082 |

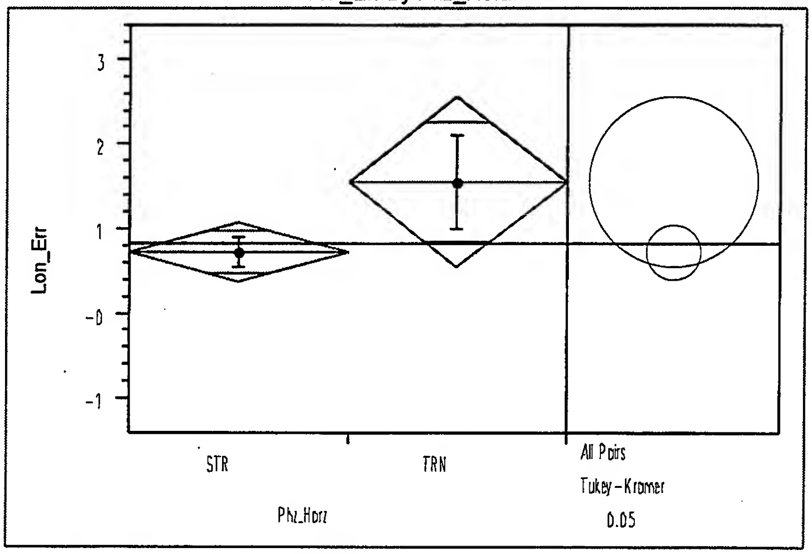
Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 0.2440 | 1 | 544.59 | 0.6216 |

t-Test
0.4939

**Figure A.2- 126 Statistical Tests for Lateral Error and Horizontal Phase of Flight at Look Ahead Time 1800 for Samples at Altitudes Above 18,000 Feet**

Lon_Err By Phz_Horz




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 3466 | 0.75035 | 10.9303 | 0.18566 |
| TRN | 446 | 1.57443 | 11.9222 | 0.56453 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | TRN | STR |
|---|---|---|
| TRN | 0.000000 | 0.824080 |
| STR | -0.82408 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96057

| Abs(Dif)-LSD | TRN | STR |
|---|---|---|
| TRN | -1.45045 | -0.26553 |
| STR | -0.26553 | -0.52030 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 3466 | 10.93034 | 7.020180 | 7.000370 |
| TRN | 446 | 11.92215 | 7.567985 | 7.456522 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 1.6369 | 1 | 3910 | 0.2008 |
| Brown-Forsythe | 1.1306 | 1 | 3910 | 0.2877 |
| Levene | 1.6508 | 1 | 3910 | 0.1989 |
| Bartlett | 6.2172 | 1 | ? | 0.0127 |

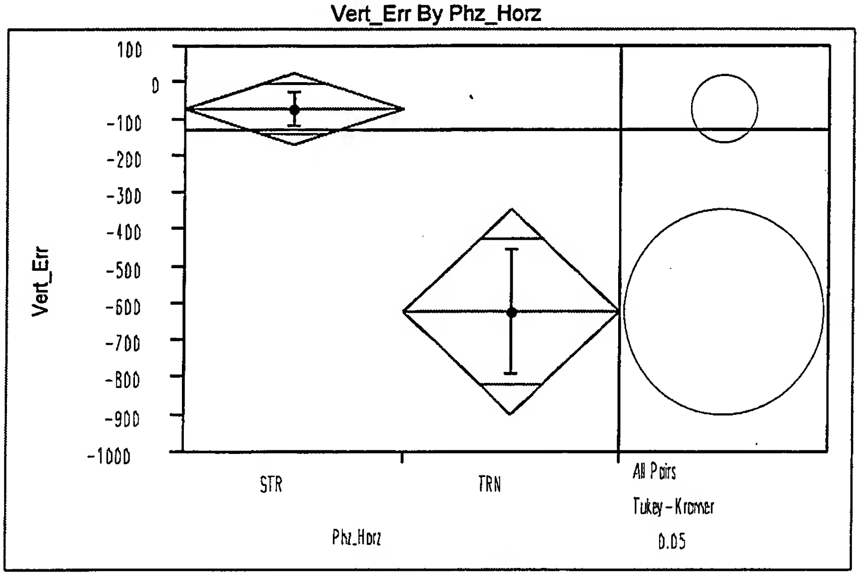
Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 1.9229 | 1 | 545.65 | 0.1661 |

| t-Test |
|---|
| 1.3867 |

**Figure A.2- 127 Statistical Tests for Longitudinal Error and Horizontal Phase of Flight at Look Ahead Time 1800 for Samples at Altitudes Above 18,000 Feet**

Vert_Err By Phz_Horz




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| STR | 3466 | -65.790 | 2982.05 | 50.65 |
| TRN | 446 | -620.819 | 3577.84 | 169.42 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | STR | TRN |
|---|---|---|
| STR | 0.000 | 555.030 |
| TRN | -555.030 | 0.000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 1.96057

| Abs(Dif)-LSD | STR | TRN |
|---|---|---|
| STR | -143.912 | 253.650 |
| TRN | 253.650 | -401.185 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| STR | 3466 | 2982.054 | 1330.937 | 1291.321 |
| TRN | 446 | 3577.840 | 2211.662 | 1900.279 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 4.8857 | 1 | 3910 | 0.0271 |
| Brown-Forsythe | 19.5504 | 1 | 3910 | <.0001 |
| Levene | 42.5162 | 1 | 3910 | <.0001 |
| Bartlett | 28.7096 | 1 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 9.8524 | 1 | 527.57 | 0.0018 |

t-Test

3.1389

**Figure A.2- 128 Statistical Tests for Vertical Error and Horizontal Phase of Flight at Look Ahead Time 1800 for Samples at Altitudes Above 18,000 Feet**

## *A.2.4 Vertical Phase of Flight Per Look Ahead Time*

### A.2.4.1 Summary Tables

| Look Ahead Time | 0 | | | 300 | | |
|---|---|---|---|---|---|---|
| Vertical Phase of Flight | Level | Ascent | Descent | Level | Ascent | Descent |
| Sample Quantity | 25326 | 4026 | 3257 | 21663 | 2333 | 3167 |
| Avg. Horz. Error | 0.25 | 0.37 | 0.36 | 2.41 | 3.9 | 3.3 |
| Stddev. Horz. Error | 0.79 | 1.14 | 0.83 | 3.04 | 3.68 | 3.5 |
| Max. Horz. Error | 48.02 | 29.51 | 17.72 | 88.45 | 46.09 | 33.42 |
| Min. Horz. Error | 0 | 0 | 0 | 0 | 0.04 | 0.02 |
| Avg. Lat. Error | 0 | 0.01 | 0.01 | 0.04 | 0.04 | -0.09 |
| Stddev. Lat. Error | 0.37 | 0.72 | 0.58 | 3.08 | 4.19 | 3.98 |
| Max. Lat. Error | 18.66 | 22.88 | 8.7 | 46.61 | 30.93 | 26.79 |
| Min. Lat. Error | -15.1 | -11.26 | -15.57 | -46.12 | -25.39 | -22.91 |
| Avg. Abs. Lat. Error | 0.11 | 0.17 | 0.19 | 1.57 | 2.44 | 2.32 |
| Stddev. Abs. Lat. Error | 0.36 | 0.7 | 0.55 | 2.65 | 3.4 | 3.23 |
| Max. Abs. Lat. Error | 18.66 | 22.88 | 15.57 | 46.61 | 30.93 | 26.79 |
| Min. Abs. Lat. Error | 0 | 0 | 0 | 0 | 0 | 0 |
| Avg. Long. Error | -0.04 | -0.04 | -0.12 | -0.11 | 0.49 | -0.08 |
| Stddev. Long. Error | 0.74 | 0.95 | 0.68 | 2.36 | 3.31 | 2.69 |
| Max. Long. Error | 47.54 | 18.64 | 4.09 | 22.74 | 46.01 | 14.86 |
| Min. Long. Error | -31.16 | -23.09 | -15 | -87.99 | -18.82 | -33.04 |
| Avg. Abs. Long. Error | 0.19 | 0.29 | 0.26 | 1.35 | 2.37 | 1.73 |
| Stddev. Abs. Long. Error | 0.72 | 0.91 | 0.64 | 1.94 | 2.36 | 2.06 |
| Max. Abs. Long. Error | 47.54 | 23.09 | 15 | 87.99 | 46.01 | 33.04 |
| Min. Abs. Long. Error | 0 | 0 | 0 | 0 | 0 | 0 |
| Avg. Vert. Error | -65.84 | -125.87 | -321.83 | -266.39 | -499.48 | -2337.55 |
| Stddev. Vert. Error | 566.14 | 1473.62 | 1001.71 | 1697.76 | 3286.46 | 2933.07 |
| Max. Vert. Error | 17000 | 18889 | 5261.11 | 26788.2 | 27290 | 9495.55 |
| Min. Vert. Error | -15565.9 | -31466.5 | -16406.8 | -18228 | -24677 | -17950 |
| Avg. Abs. Vert. Error | 103.29 | 299.9 | 367.97 | 652.46 | 2379.7 | 2889.35 |
| Stddev. Abs. Vert. Error | 560.52 | 1448.25 | 985.69 | 1589.85 | 2320.56 | 2391.19 |
| Max. Abs. Vert. Error | 17000 | 31466.46 | 16406.83 | 26788.2 | 27290 | 17950 |
| Min. Abs. Vert. Error | 0 | 0 | 0 | 0 | 0 | 0 |
| Avg. Slant Range Error | 0.25 | 0.38 | 0.37 | 2.42 | 3.95 | 3.39 |
| Stddev. Slant Range Error | 0.8 | 1.16 | 0.84 | 3.04 | 3.67 | 3.46 |
| Max. Slant Range Error | 48.03 | 29.51 | 17.73 | 88.56 | 46.09 | 33.42 |
| Min. Slant Range Error | 0 | 0 | 0 | 0.01 | 0.09 | 0.06 |

**Figure A.2- 129 Descriptive Statistics for Vertical Phase of Flight per Look Ahead Time for Samples at All Altitudes**

| Look Ahead Time | 600 | | | 900 | | |
|---|---|---|---|---|---|---|
| Vertical Phase of Flight | Level | Ascent | Descent | Level | Ascent | Descent |
| Sample Quantity | 18016 | 1014 | 2878 | 14314 | 304 | 2323 |
| Avg. Horz. Error | 4.33 | 6.92 | 4.91 | 6.13 | 9.87 | 6.23 |
| Stddev. Horz. Error | 4.9 | 5.81 | 4.71 | 6.57 | 8.49 | 6.05 |
| Max. Horz. Error | 65.69 | 40.91 | 67.08 | 86.49 | 56.6 | 101.09 |
| Min. Horz. Error | 0.01 | 0.06 | 0.02 | 0.01 | 0.13 | 0.02 |
| Avg. Lat. Error | 0.29 | 0.45 | -0.18 | 0.54 | 1.99 | -0.2 |
| Stddev. Lat. Error | 4.9 | 6.74 | 5.13 | 6.34 | 10 | 5.58 |
| Max. Lat. Error | 55.5 | 38.94 | 33.84 | 60.84 | 54.78 | 31.18 |
| Min. Lat. Error | -38.27 | -33.24 | -34.23 | -43.96 | -34.75 | -64.27 |
| Avg. Abs. Lat. Error | 2.54 | 3.6 | 3.03 | 3.29 | 5.54 | 3.3 |
| Stddev. Abs. Lat. Error | 4.2 | 5.71 | 4.14 | 5.44 | 8.56 | 4.5 |
| Max. Abs. Lat. Error | 55.5 | 38.94 | 34.23 | 60.84 | 54.78 | 64.27 |
| Min. Abs. Lat. Error | 0 | 0 | 0 | 0 | 0 | 0 |
| Avg. Long. Error | 0.17 | 2.04 | 0.45 | 0.57 | 1.51 | 0.98 |
| Stddev. Long. Error | 4.32 | 5.66 | 4.45 | 6.32 | 7.97 | 6.58 |
| Max. Long. Error | 54.4 | 19.77 | 59.63 | 58.31 | 25.7 | 41.14 |
| Min. Long. Error | -59.56 | -29.72 | -25.16 | -83.04 | -36.79 | -78.02 |
| Avg. Abs. Long. Error | 2.69 | 4.72 | 3.02 | 4.06 | 6.29 | 4.32 |
| Stddev. Abs. Long. Error | 3.39 | 3.72 | 3.3 | 4.88 | 5.11 | 5.06 |
| Max. Abs. Long. Error | 59.56 | 29.72 | 59.63 | 83.04 | 36.79 | 78.02 |
| Min. Abs. Long. Error | 0 | 0.01 | 0 | 0 | 0 | 0 |
| Avg. Vert. Error | -335.38 | -539.09 | -3494.58 | -424.39 | -189.58 | -4017.92 |
| Stddev. Vert. Error | 2323.44 | 4371.02 | 3530.09 | 2859.83 | 4704.35 | 4223.02 |
| Max. Vert. Error | 28990 | 25190 | 10649 | 29003 | 28017 | 24098 |
| Min. Vert. Error | -21075.3 | -14510 | -26868 | -21566 | -9900 | -32426 |
| Avg. Abs. Vert. Error | 1030.99 | 3176.39 | 3873.94 | 1317.35 | 3121.12 | 4494.61 |
| Stddev. Abs. Vert. Error | 2108.99 | 3049.15 | 3108.89 | 2573.56 | 3520.43 | 3711.37 |
| Max. Abs. Vert. Error | 28990 | 25190 | 26868 | 29003 | 28017 | 32426 |
| Min. Abs. Vert. Error | 0 | 1 | 0 | 0 | 14 | 0.37 |
| Avg. Slant Range Error | 4.35 | 6.97 | 5.03 | 6.15 | 9.91 | 6.35 |
| Stddev. Slant Range Error | 4.9 | 5.8 | 4.67 | 6.57 | 8.47 | 6 |
| Max. Slant Range Error | 65.69 | 40.91 | 67.09 | 86.49 | 56.6 | 101.09 |
| Min. Slant Range Error | 0.01 | 0.2 | 0.11 | 0.01 | 0.69 | 0.13 |

**Figure A.2- 130 Descriptive Statistics for Vertical Phase of Flight per Look Ahead Time for Samples at All Altitudes**

| Look Ahead Time | 1200 | | | 1500 | | |
|---|---|---|---|---|---|---|
| Vertical Phase of Flight | Level | Ascent | Descent | Level | Ascent | Descent |
| Sample Quantity | 10969 | 97 | 1855 | 7967 | 39 | 1255 |
| Avg. Horz. Error | 7.81 | 12.2 | 7.67 | 9.48 | 13.87 | 8.75 |
| Stddev. Horz. Error | 8.11 | 9.5 | 8 | 9.8 | 9.12 | 9.43 |
| Max. Horz. Error | 103.04 | 40.57 | 86.73 | 87.22 | 32.25 | 94.14 |
| Min. Horz. Error | 0.01 | 0.22 | 0.02 | 0.03 | 0.46 | 0.13 |
| Avg. Lat. Error | 0.69 | 2.7 | -0.29 | 0.59 | 2.89 | -0.42 |
| Stddev. Lat. Error | 7.61 | 11.59 | 6.08 | 8.79 | 11.28 | 6.6 |
| Max. Lat. Error | 76.1 | 39.99 | 39.35 | 85.67 | 31.6 | 32.52 |
| Min. Lat. Error | -55.56 | -30.13 | -44.51 | -65.63 | -22.26 | -55.21 |
| Avg. Abs. Lat. Error | 3.94 | 6.67 | 3.6 | 4.48 | 7.33 | 3.93 |
| Stddev. Abs. Lat. Error | 6.54 | 9.84 | 4.91 | 7.59 | 8.98 | 5.32 |
| Max. Abs. Lat. Error | 76.1 | 39.99 | 44.51 | 85.67 | 31.6 | 55.21 |
| Min. Abs. Lat. Error | 0 | 0.01 | 0 | 0 | 0.03 | 0 |
| Avg. Long. Error | 1.09 | 2.75 | 1.75 | 1.72 | 4.99 | 2.64 |
| Stddev. Long. Error | 8.2 | 9.55 | 9.09 | 10.26 | 10.91 | 10.72 |
| Max. Long. Error | 53.21 | 26.71 | 77.59 | 86.1 | 25.91 | 94.14 |
| Min. Long. Error | -94.35 | -20.53 | -85.87 | -64.82 | -16.12 | -73.71 |
| Avg. Abs. Long. Error | 5.4 | 7.87 | 5.69 | 6.8 | 9.71 | 6.67 |
| Stddev. Abs. Long. Error | 6.27 | 6.03 | 7.31 | 7.88 | 6.92 | 8.79 |
| Max. Abs. Long. Error | 94.35 | 26.71 | 85.87 | 86.1 | 25.91 | 94.14 |
| Min. Abs. Long. Error | 0 | 0.09 | 0 | 0 | 0.12 | 0 |
| Avg. Vert. Error | -536.07 | -380.64 | -4145.37 | -653.47 | 332.41 | -4355.58 |
| Stddev. Vert. Error | 3091.44 | 3302.06 | 4589.18 | 3216.44 | 2442.86 | 4808.4 |
| Max. Vert. Error | 29003 | 15050 | 28590 | 29003 | 5086 | 13797 |
| Min. Vert. Error | -26558 | -6427.62 | -28868 | -22800 | -5981 | -27901 |
| Avg. Abs. Vert. Error | 1459.99 | 2476.87 | 4756.35 | 1565.95 | 1992.82 | 4964.09 |
| Stddev. Abs. Vert. Error | 2777.16 | 2202.54 | 3952.07 | 2884.45 | 1416.02 | 4176.73 |
| Max. Abs. Vert. Error | 29003 | 15050 | 28868 | 29003 | 5981 | 27901 |
| Min. Abs. Vert. Error | 0 | 5 | 0 | 0 | 112 | 4.4 |
| Avg. Slant Range Error | 7.83 | 12.23 | 7.79 | 9.51 | 13.88 | 8.87 |
| Stddev. Slant Range Error | 8.1 | 9.48 | 7.95 | 9.79 | 9.11 | 9.38 |
| Max. Slant Range Error | 103.05 | 40.57 | 86.86 | 87.23 | 32.25 | 94.14 |
| Min. Slant Range Error | 0.01 | 0.8 | 0.19 | 0.03 | 0.52 | 0.22 |

**Figure A.2- 131 Descriptive Statistics for Vertical Phase of Flight per Look Ahead Time for Samples at All Altitudes**

| Look Ahead Time | 1800 | | | | | |
|---|---|---|---|---|---|---|
| Vertical Phase of Flight | Level | Ascent | Descent | Level | Ascent | Descent |
| Sample Quantity | 5745 | 13 | 899 | | | |
| Avg. Horz. Error | 11.07 | 18.41 | 10.01 | | | |
| Stddev. Horz. Error | 11.37 | 10.83 | 10.11 | | | |
| Max. Horz. Error | 96.9 | 37.99 | 98.82 | | | |
| Min. Horz. Error | 0.03 | 3.5 | 0.11 | | | |
| Avg. Lat. Error | 0.6 | 8.51 | -0.59 | | | |
| Stddev. Lat. Error | 9.59 | 13.95 | 7.83 | | | |
| Max. Lat. Error | 86.54 | 27.63 | 26.02 | | | |
| Min. Lat. Error | -62.21 | -19.27 | -59.89 | | | |
| Avg. Abs. Lat. Error | 4.9 | 12.19 | 4.56 | | | |
| Stddev. Abs. Lat. Error | 8.26 | 10.59 | 6.4 | | | |
| Max. Abs. Lat. Error | 86.54 | 27.63 | 59.89 | | | |
| Min. Abs. Lat. Error | 0 | 0.01 | 0 | | | |
| Avg. Long. Error | 2.3 | 1.44 | 3.24 | | | |
| Stddev. Long. Error | 12.42 | 14.47 | 11.41 | | | |
| Max. Long. Error | 96.86 | 18.76 | 59.82 | | | |
| Min. Long. Error | -77.43 | -26.07 | -78.6 | | | |
| Avg. Abs. Long. Error | 8.2 | 11.51 | 7.65 | | | |
| Stddev. Abs. Long. Error | 9.62 | 8.25 | 9.07 | | | |
| Max. Abs. Long. Error | 96.86 | 26.07 | 78.6 | | | |
| Min. Abs. Long. Error | 0 | 0.16 | 0 | | | |
| Avg. Vert. Error | -741.01 | 1569.38 | -4666.23 | | | |
| Stddev. Vert. Error | 3391.9 | 2217.34 | 4881.61 | | | |
| Max. Vert. Error | 29003 | 5896 | 6933 | | | |
| Min. Vert. Error | -24600 | -2690 | -29635 | | | |
| Avg. Abs. Vert. Error | 1698.16 | 2148.15 | 5136.5 | | | |
| Stddev. Abs. Vert. Error | 3028.19 | 1608.01 | 4383.5 | | | |
| Max. Abs. Vert. Error | 29003 | 5896 | 29635 | | | |
| Min. Abs. Vert. Error | 0 | 532 | 0 | | | |
| Avg. Slant Range Error | 11.09 | 18.42 | 10.12 | | | |
| Stddev. Slant Range Error | 11.36 | 10.82 | 10.06 | | | |
| Max. Slant Range Error | 96.91 | 37.99 | 98.82 | | | |
| Min. Slant Range Error | 0.03 | 3.56 | 0.27 | | | |

**Figure A.2- 132 Descriptive Statistics for Vertical Phase of Flight per Look Ahead Time for Samples at All Altitudes**

| Look Ahead Time | 0 | | | 300 | | |
|---|---|---|---|---|---|---|
| Vertical Phase of Flight | Level | Ascent | Descent | Level | Ascent | Descent |
| Sample Quantity | 17187 | 2208 | 1814 | 14807 | 1911 | 1733 |
| Avg. Horz. Error | 0.22 | 0.42 | 0.31 | 2.26 | 3.76 | 3.2 |
| Stddev. Horz. Error | 0.64 | 1.34 | 0.69 | 3.16 | 3.66 | 3.75 |
| Max. Horz. Error | 48.02 | 29.51 | 17.72 | 88.45 | 46.09 | 27.72 |
| Min. Horz. Error | 0 | 0 | 0 | 0 | 0.04 | 0.02 |
| Avg. Lat. Error | 0 | 0.03 | -0.01 | 0.08 | 0.15 | -0.22 |
| Stddev. Lat. Error | 0.29 | 0.84 | 0.55 | 3.22 | 4.16 | 4.41 |
| Max. Lat. Error | 13.61 | 22.88 | 8.7 | 46.61 | 30.93 | 26.79 |
| Min. Lat. Error | -6.81 | -10.95 | -15.57 | -46.12 | -22.33 | -22.91 |
| Avg. Abs. Lat. Error | 0.09 | 0.19 | 0.16 | 1.53 | 2.36 | 2.49 |
| Stddev. Abs. Lat. Error | 0.28 | 0.82 | 0.52 | 2.83 | 3.43 | 3.64 |
| Max. Abs. Lat. Error | 13.61 | 22.88 | 15.57 | 46.61 | 30.93 | 26.79 |
| Min. Abs. Lat. Error | 0 | 0 | 0 | 0 | 0 | 0 |
| Avg. Long. Error | -0.04 | -0.01 | -0.09 | -0.06 | 0.94 | -0.05 |
| Stddev. Long. Error | 0.61 | 1.13 | 0.51 | 2.16 | 3.06 | 2.2 |
| Max. Long. Error | 47.54 | 18.64 | 3.56 | 22.18 | 46.01 | 14.86 |
| Min. Long. Error | -31.16 | -23.09 | -10.07 | -87.99 | -16.2 | -14.59 |
| Avg. Abs. Long. Error | 0.17 | 0.33 | 0.22 | 1.18 | 2.27 | 1.42 |
| Stddev. Abs. Long. Error | 0.59 | 1.08 | 0.47 | 1.81 | 2.25 | 1.69 |
| Max. Abs. Long. Error | 47.54 | 23.09 | 10.07 | 87.99 | 46.01 | 14.86 |
| Min. Abs. Long. Error | 0 | 0 | 0 | 0 | 0 | 0 |
| Avg. Vert. Error | 2.79 | -23.34 | -202.07 | 53.33 | -109.4 | -1861.93 |
| Stddev. Vert. Error | 262.98 | 1122.12 | 832.64 | 1205.18 | 2889.78 | 2960.92 |
| Max. Vert. Error | 17000 | 18889 | 5261.11 | 26788.2 | 27290 | 9495.55 |
| Min. Vert. Error | -11767 | -21500 | -16406.8 | -18228 | -10819.2 | -17950 |
| Avg. Abs. Vert. Error | 30.82 | 250.36 | 249.73 | 340.67 | 2048.96 | 2653.41 |
| Stddev. Abs. Vert. Error | 261.19 | 1094.07 | 819.6 | 1157.26 | 2040.2 | 2278.41 |
| Max. Abs. Vert. Error | 17000 | 21500 | 16406.83 | 26788.2 | 27290 | 17950 |
| Min. Abs. Vert. Error | 0 | 0 | 0 | 0 | 0 | 0 |
| Avg. Slant Range Error | 0.22 | 0.43 | 0.31 | 2.27 | 3.81 | 3.3 |
| Stddev. Slant Range Error | 0.64 | 1.35 | 0.7 | 3.16 | 3.65 | 3.72 |
| Max. Slant Range Error | 48.03 | 29.51 | 17.73 | 88.56 | 46.09 | 27.72 |
| Min. Slant Range Error | 0 | 0 | 0 | 0.01 | 0.09 | 0.06 |

**Figure A.2- 133 Descriptive Statistics for Vertical Phase of Flight per Look Ahead Time for Samples at Altitudes Above 18,000 Feet**

| Look Ahead Time | 600 | | | 900 | | |
|---|---|---|---|---|---|---|
| Vertical Phase of Flight | Level | Ascent | Descent | Level | Ascent | Descent |
| Sample Quantity | 12322 | 945 | 1540 | 9768 | 289 | 1160 |
| Avg. Horz. Error | 4.16 | 6.99 | 4.82 | 6.05 | 9.94 | 5.79 |
| Stddev. Horz. Error | 5.02 | 5.93 | 5.21 | 6.8 | 8.59 | 5.61 |
| Max. Horz. Error | 57.5 | 40.91 | 67.08 | 75.25 | 56.6 | 43.7 |
| Min. Horz. Error | 0.01 | 0.06 | 0.02 | 0.01 | 0.13 | 0.06 |
| Avg. Lat. Error | 0.4 | 0.63 | -0.42 | 0.76 | 2.04 | -0.44 |
| Stddev. Lat. Error | 5.17 | 6.84 | 5.77 | 6.88 | 10.17 | 5.87 |
| Max. Lat. Error | 55.5 | 38.94 | 33.84 | 60.84 | 54.78 | 31.18 |
| Min. Lat. Error | -38.27 | -33.24 | -34.23 | -43.96 | -34.75 | -35.37 |
| Avg. Abs. Lat. Error | 2.57 | 3.61 | 3.38 | 3.48 | 5.66 | 3.5 |
| Stddev. Abs. Lat. Error | 4.5 | 5.84 | 4.7 | 5.98 | 8.69 | 4.74 |
| Max. Abs. Lat. Error | 55.5 | 38.94 | 34.23 | 60.84 | 54.78 | 35.37 |
| Min. Abs. Lat. Error | 0 | 0 | 0 | 0 | 0 | 0 |
| Avg. Long. Error | 0.17 | 2.35 | 0.2 | 0.4 | 1.84 | 0.37 |
| Stddev. Long. Error | 3.96 | 5.61 | 4.11 | 5.89 | 7.87 | 5.5 |
| Max. Long. Error | 54.4 | 19.77 | 59.63 | 58.31 | 25.7 | 41.14 |
| Min. Long. Error | -28 | -29.72 | -21.01 | -61.99 | -36.79 | -21.74 |
| Avg. Abs. Long. Error | 2.44 | 4.77 | 2.56 | 3.75 | 6.28 | 3.58 |
| Stddev. Abs. Long. Error | 3.13 | 3.77 | 3.23 | 4.57 | 5.08 | 4.19 |
| Max. Abs. Long. Error | 54.4 | 29.72 | 59.63 | 61.99 | 36.79 | 41.14 |
| Min. Abs. Long. Error | 0 | 0.03 | 0 | 0 | 0 | 0 |
| Avg. Vert. Error | 65.83 | -380.28 | -3032.69 | 98.92 | -84.47 | -3397.46 |
| Stddev. Vert. Error | 2040.95 | 4319.61 | 3379.09 | 2565.73 | 4762.72 | 4004.29 |
| Max. Vert. Error | 28990 | 25190 | 10649 | 29003 | 28017 | 24098 |
| Min. Vert. Error | -13004 | -14510 | -16708 | -17000 | -9900 | -20550 |
| Avg. Abs. Vert. Error | 736.19 | 3083.65 | 3537.88 | 972.68 | 3135.07 | 4068.74 |
| Stddev. Abs. Vert. Error | 1904.67 | 3047.09 | 2845.48 | 2376.24 | 3581.59 | 3319.36 |
| Max. Abs. Vert. Error | 28990 | 25190 | 16708 | 29003 | 28017 | 24098 |
| Min. Abs. Vert. Error | 0 | 1 | 0 | 0 | 14 | 13.63 |
| Avg. Slant Range Error | 4.18 | 7.04 | 4.93 | 6.07 | 9.99 | 5.9 |
| Stddev. Slant Range Error | 5.02 | 5.92 | 5.17 | 6.79 | 8.57 | 5.56 |
| Max. Slant Range Error | 57.5 | 40.91 | 67.09 | 75.4 | 56.6 | 43.71 |
| Min. Slant Range Error | 0.01 | 0.2 | 0.11 | 0.01 | 0.69 | 0.13 |

**Figure A.2- 134 Descriptive Statistics for Vertical Phase of Flight per Look Ahead Time for Samples at Altitudes Above 18,000 Feet**

| Look Ahead Time | 1200 | | | 1500 | | |
|---|---|---|---|---|---|---|
| Vertical Phase of Flight | Level | Ascent | Descent | Level | Ascent | Descent |
| Sample Quantity | 7238 | 95 | 856 | 5111 | 36 | 558 |
| Avg. Horz. Error | 7.78 | 12.32 | 7.42 | 9.22 | 13.88 | 8 |
| Stddev. Horz. Error | 8.38 | 9.55 | 8.56 | 10.02 | 9.28 | 7.69 |
| Max. Horz. Error | 78.4 | 40.57 | 86.73 | 87.22 | 32.25 | 64.14 |
| Min. Horz. Error | 0.01 | 0.22 | 0.02 | 0.03 | 0.46 | 0.13 |
| Avg. Lat. Error | 1 | 2.79 | -0.51 | 0.93 | 3.19 | -0.88 |
| Stddev. Lat. Error | 8.35 | 11.69 | 6.58 | 9.7 | 11.66 | 6.9 |
| Max. Lat. Error | 76.1 | 39.99 | 39.35 | 85.67 | 31.6 | 21.76 |
| Min. Lat. Error | -55.56 | -30.13 | -36.62 | -65.63 | -22.26 | -41.85 |
| Avg. Abs. Lat. Error | 4.28 | 6.77 | 3.89 | 4.87 | 7.71 | 4.24 |
| Stddev. Abs. Lat. Error | 7.24 | 9.92 | 5.33 | 8.44 | 9.24 | 5.52 |
| Max. Abs. Lat. Error | 76.1 | 39.99 | 39.35 | 85.67 | 31.6 | 41.85 |
| Min. Abs. Lat. Error | 0 | 0.01 | 0 | 0 | 0.03 | 0 |
| Avg. Long. Error | 0.66 | 2.72 | 0.81 | 0.8 | 4.3 | 0.64 |
| Stddev. Long. Error | 7.71 | 9.62 | 9.17 | 9.49 | 10.89 | 8.62 |
| Max. Long. Error | 53.21 | 26.71 | 77.59 | 61.01 | 25.91 | 63.91 |
| Min. Long. Error | -48.76 | -20.53 | -85.87 | -61.99 | -16.12 | -32.01 |
| Avg. Abs. Long. Error | 5.01 | 7.91 | 5.14 | 6.13 | 9.41 | 5.53 |
| Stddev. Abs. Long. Error | 5.9 | 6.05 | 7.64 | 7.29 | 6.83 | 6.65 |
| Max. Abs. Long. Error | 53.21 | 26.71 | 85.87 | 61.99 | 25.91 | 63.91 |
| Min. Abs. Long. Error | 0 | 0.09 | 0.01 | 0 | 0.12 | 0 |
| Avg. Vert. Error | 187.11 | -408.74 | -3460.7 | 160.58 | 433.06 | -3346.38 |
| Stddev. Vert. Error | 2586.64 | 3331.19 | 4468.07 | 2589.52 | 2245.76 | 4315.48 |
| Max. Vert. Error | 29003 | 15050 | 28590 | 29003 | 5086 | 13797 |
| Min. Vert. Error | -16883 | -6427.62 | -19633 | -17000 | -3589 | -20550 |
| Avg. Abs. Vert. Error | 972.97 | 2508.94 | 4350.88 | 997.14 | 1893.33 | 4259.77 |
| Stddev. Abs. Vert. Error | 2403.93 | 2214.49 | 3605.79 | 2395.19 | 1244.66 | 3415.18 |
| Max. Abs. Vert. Error | 29003 | 15050 | 28590 | 29003 | 5086 | 20550 |
| Min. Abs. Vert. Error | 0 | 5 | 0 | 0 | 183 | 4.4 |
| Avg. Slant Range Error | 7.79 | 12.34 | 7.54 | 9.24 | 13.89 | 8.09 |
| Stddev. Slant Range Error | 8.38 | 9.54 | 8.51 | 10.02 | 9.26 | 7.65 |
| Max. Slant Range Error | 78.4 | 40.57 | 86.86 | 87.23 | 32.25 | 64.17 |
| Min. Slant Range Error | 0.01 | 0.8 | 0.21 | 0.03 | 0.52 | 0.22 |

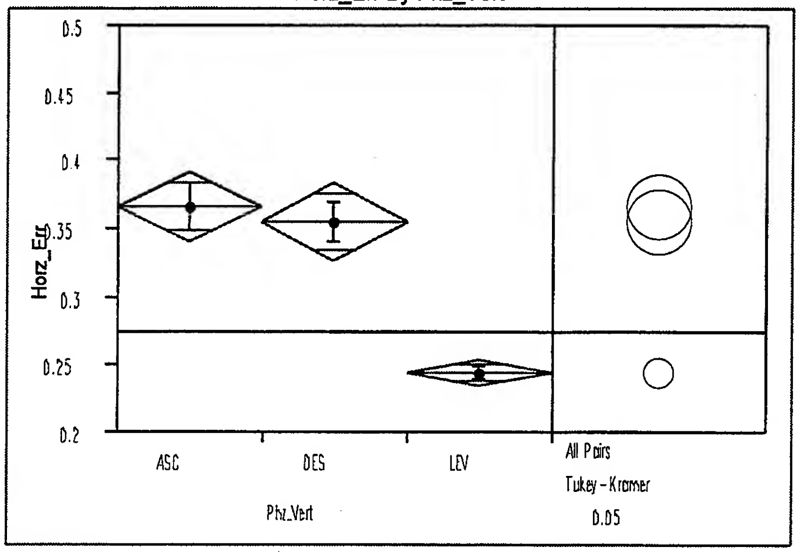
**Figure A.2- 135 Descriptive Statistics for Vertical Phase of Flight per Look Ahead Time for Samples at Altitudes Above 18,000 Feet**

| Look Ahead Time | 1800 | | | | | |
|---|---|---|---|---|---|---|
| Vertical Phase of Flight | Level | Ascent | Descent | Level | Ascent | Descent |
| Sample Quantity | 3512 | 13 | 392 | | | |
| Avg. Horz. Error | 10.51 | 18.41 | 8.56 | | | |
| Stddev. Horz. Error | 11.37 | 10.83 | 7.71 | | | |
| Max. Horz. Error | 87.65 | 37.99 | 51.25 | | | |
| Min. Horz. Error | 0.03 | 3.5 | 0.11 | | | |
| Avg. Lat. Error | 0.91 | 8.51 | -1.33 | | | |
| Stddev. Lat. Error | 10.49 | 13.95 | 8.21 | | | |
| Max. Lat. Error | 86.54 | 27.63 | 20.43 | | | |
| Min. Lat. Error | -62.21 | -19.27 | -51.14 | | | |
| Avg. Abs. Lat. Error | 5.25 | 12.19 | 4.93 | | | |
| Stddev. Abs. Lat. Error | 9.13 | 10.59 | 6.7 | | | |
| Max. Abs. Lat. Error | 86.54 | 27.63 | 51.14 | | | |
| Min. Abs. Lat. Error | 0 | 0.01 | 0 | | | |
| Avg. Long. Error | 0.79 | 1.44 | 1.22 | | | |
| Stddev. Long. Error | 11.33 | 14.47 | 7.88 | | | |
| Max. Long. Error | 77.47 | 18.76 | 37.81 | | | |
| Min. Long. Error | -58.65 | -26.07 | -23.84 | | | |
| Avg. Abs. Long. Error | 7.19 | 11.51 | 5.66 | | | |
| Stddev. Abs. Long. Error | 8.79 | 8.25 | 5.62 | | | |
| Max. Abs. Long. Error | 77.47 | 26.07 | 37.81 | | | |
| Min. Abs. Long. Error | 0 | 0.16 | 0 | | | |
| Avg. Vert. Error | 268.41 | 1569.38 | -3744.79 | | | |
| Stddev. Vert. Error | 2605.18 | 2217.34 | 4239.04 | | | |
| Max. Vert. Error | 29003 | 5896 | 6933 | | | |
| Min. Vert. Error | -16883 | -2690 | -17851 | | | |
| Avg. Abs. Vert. Error | 1009.74 | 2148.15 | 4462.2 | | | |
| Stddev. Abs. Vert. Error | 2416.44 | 1608.01 | 3473.71 | | | |
| Max. Abs. Vert. Error | 29003 | 5896 | 17851 | | | |
| Min. Abs. Vert. Error | 0 | 532 | 0 | | | |
| Avg. Slant Range Error | 10.53 | 18.42 | 8.65 | | | |
| Stddev. Slant Range Error | 11.37 | 10.82 | 7.67 | | | |
| Max. Slant Range Error | 87.65 | 37.99 | 51.27 | | | |
| Min. Slant Range Error | 0.03 | 3.56 | 0.27 | | | |

**Figure A.2- 136 Descriptive Statistics for Vertical Phase of Flight per Look Ahead Time for Samples at Altitudes Above 18,000 Feet**

## A.2.4.2 Statistical Tests

Horz_Err By Phz_Vert




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 4019 | 0.370118 | 1.13606 | 0.01792 |
| DES | 3252 | 0.362882 | 0.83058 | 0.01456 |
| LEV | 25288 | 0.249126 | 0.79500 | 0.00500 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | ASC | DES | LEV |
|---|---|---|---|
| ASC | 0.000000 | 0.007236 | 0.120993 |
| DES | -0.00724 | 0.000000 | 0.113756 |
| LEV | -0.12099 | -0.11376 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34381

| Abs(Dif)-LSD | ASC | DES | LEV |
|---|---|---|---|
| ASC | -0.04434 | -0.03964 | 0.087242 |
| DES | -0.03964 | -0.04929 | 0.076730 |
| LEV | 0.087242 | 0.076730 | -0.01768 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

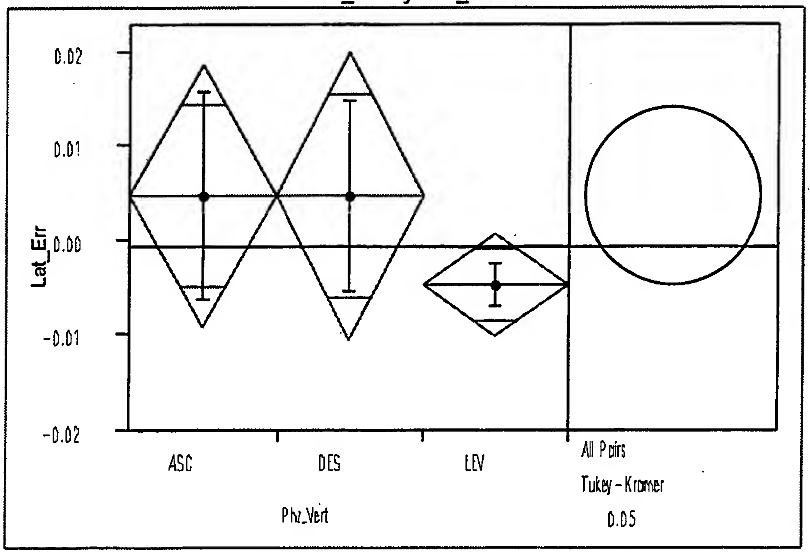
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 4019 | 1.136064 | 0.3380860 | 0.2813107 |
| DES | 3252 | 0.830579 | 0.3257492 | 0.2739248 |
| LEV | 25288 | 0.795003 | 0.2205126 | 0.1819284 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 2.3366 | 2 | 32556 | 0.0967 |
| Brown-Forsythe | 37.5207 | 2 | 32556 | <.0001 |
| Levene | 54.2052 | 2 | 32556 | <.0001 |
| Bartlett | 523.9514 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 44.5759 | 2 | 5691.2 | <.0001 |

**Figure A.2- 137 Statistical Tests for Horizontal Error and Vertical Phase of Flight at Look Ahead Time 0 for Samples at All Altitudes**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 4019 | 0.007652 | 0.716016 | 0.01129 |
| DES | 3252 | 0.007661 | 0.582285 | 0.01021 |
| LEV | 25288 | -0.00172 | 0.375069 | 0.00236 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | DES | ASC | LEV |
|---|---|---|---|
| DES | 0.000000 | 0.000009 | 0.009380 |
| ASC | -9.13e-6 | 0.000000 | 0.009371 |
| LEV | -0.00938 | -0.00937 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34381

| Abs(Dif)-LSD | DES | ASC | LEV |
|---|---|---|---|
| DES | -0.02641 | -0.02511 | -0.01046 |
| ASC | -0.02511 | -0.02375 | -0.00871 |
| LEV | -0.01046 | -0.00871 | -0.00947 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

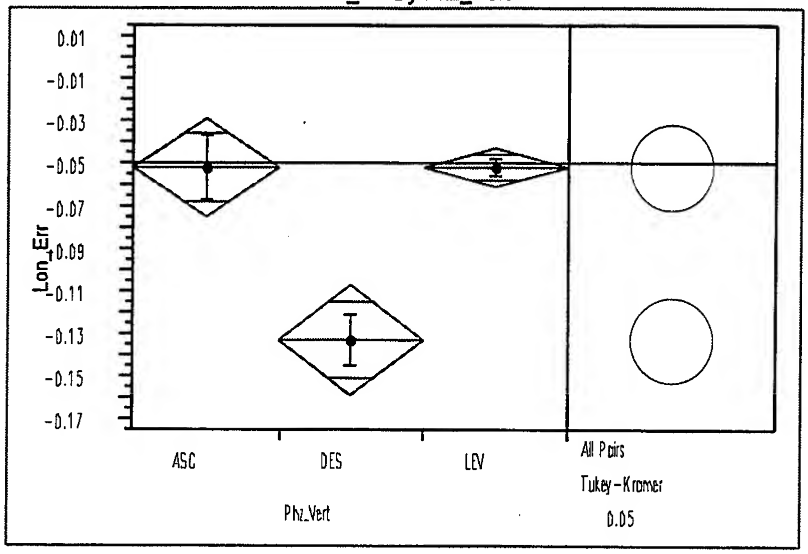
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 4019 | 0.7160160 | 0.1714768 | 0.1705436 |
| DES | 3252 | 0.5822854 | 0.1895395 | 0.1883966 |
| LEV | 25288 | 0.3750692 | 0.1111693 | 0.1111493 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 11.6147 | 2 | 32556 | <.0001 |
| Brown-Forsythe | 69.0923 | 2 | 32556 | <.0001 |
| Levene | 71.2014 | 2 | 32556 | <.0001 |
| Bartlett | 2211.8958 | 2 | ? | 0.0000 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 0.6983 | 2 | 5247.3 | 0.4975 |

**Figure A.2- 138 Statistical Tests for Lateral Error and Vertical Phase of Flight at Look Ahead Time 0 for Samples at All Altitudes**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 4019 | -0.04291 | 0.955554 | 0.01507 |
| DES | 3252 | -0.11723 | 0.684633 | 0.01201 |
| LEV | 25288 | -0.04202 | 0.742731 | 0.00467 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | LEV | ASC | DES |
|---|---|---|---|
| LEV | 0.000000 | 0.000891 | 0.075202 |
| ASC | -0.00089 | 0.000000 | 0.074311 |
| DES | -0.0752 | -0.07431 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34381

| Abs(Dif)-LSD | LEV | ASC | DES |
|---|---|---|---|
| LEV | -0.01598 | -0.02963 | 0.041721 |
| ASC | -0.02963 | -0.04009 | 0.031921 |
| DES | 0.041721 | 0.031921 | -0.04457 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

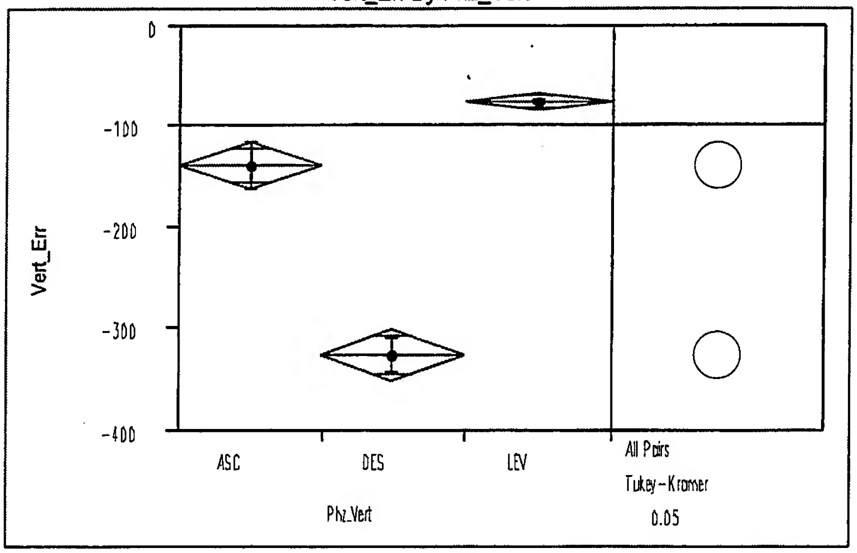
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 4019 | 0.9555537 | 0.2802567 | 0.2797467 |
| DES | 3252 | 0.6846330 | 0.2566226 | 0.2492945 |
| LEV | 25288 | 0.7427308 | 0.1867056 | 0.1866858 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 0.9426 | 2 | 32556 | 0.3896 |
| Brown-Forsythe | 34.2053 | 2 | 32556 | <.0001 |
| Levene | 36.6214 | 2 | 32556 | <.0001 |
| Bartlett | 290.5073 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 17.2019 | 2 | 5911.8 | <.0001 |

**Figure A.2- 139 Statistical Tests for Longitudinal Error and Vertical Phase of Flight at Look Ahead Time 0 for Samples at All Altitudes**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 4019 | -126.129 | 1474.88 | 23.265 |
| DES | 3252 | -322.302 | 1002.40 | 17.578 |
| LEV | 25288 | -65.622 | 563.81 | 3.545 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | LEV | ASC | DES |
|---|---|---|---|
| LEV | 0.000 | 60.507 | 256.679 |
| ASC | -60.507 | 0.000 | 196.173 |
| DES | -256.679 | -196.173 | 0.000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34381

| Abs(Dif)-LSD | LEV | ASC | DES |
|---|---|---|---|
| LEV | -16.356 | 29.276 | 222.418 |
| ASC | 29.276 | -41.027 | 152.794 |
| DES | 222.418 | 152.794 | -45.609 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 4019 | 1474.884 | 335.4700 | 298.8143 |
| DES | 3252 | 1002.402 | 398.4713 | 335.1945 |
| LEV | 25288 | 563.811 | 145.4466 | 103.0482 |

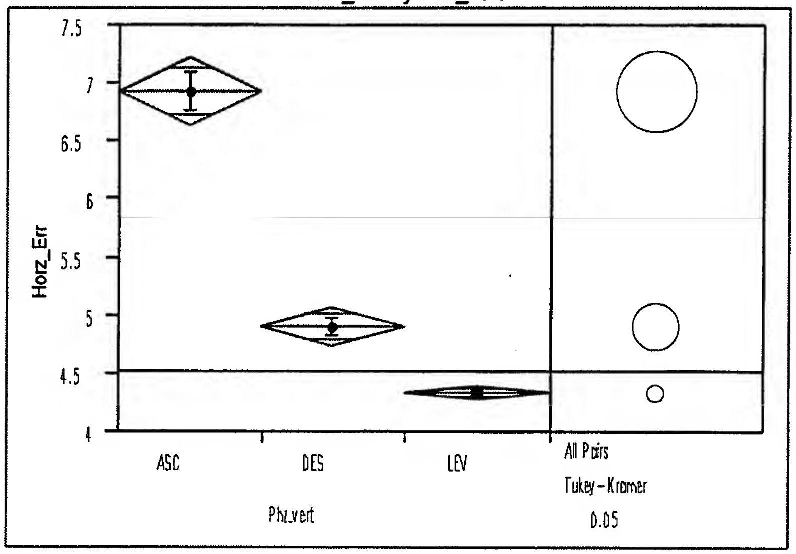
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 37.7008 | 2 | 32556 | <.0001 |
| Brown-Forsythe | 215.7726 | 2 | 32556 | <.0001 |
| Levene | 242.3140 | 2 | 32556 | <.0001 |
| Bartlett | 5026.4204 | 2 | ? | 0.0000 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 104.7353 | 2 | 5100.8 | <.0001 |

**Figure A.2- 140 Statistical Tests for Vertical Error and Vertical Phase of Flight at Look Ahead Time 0 for Samples at All Altitudes**

Horz_Err By Phz_vert




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 1014 | 6.92099 | 5.81365 | 0.18257 |
| DES | 2875 | 4.90505 | 4.70164 | 0.08769 |
| LEV | 17990 | 4.33287 | 4.90285 | 0.03655 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | ASC | DES | LEV |
|---|---|---|---|
| ASC | 0.00000 | 2.01594 | 2.58812 |
| DES | -2.01594 | 0.00000 | 0.57218 |
| LEV | -2.58812 | -0.57218 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34386

| Abs(Dif)-LSD | ASC | DES | LEV |
|---|---|---|---|
| ASC | -0.51246 | 1.59450 | 2.21569 |
| DES | 1.59450 | -0.30434 | 0.34042 |
| LEV | 2.21569 | 0.34042 | -0.12166 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

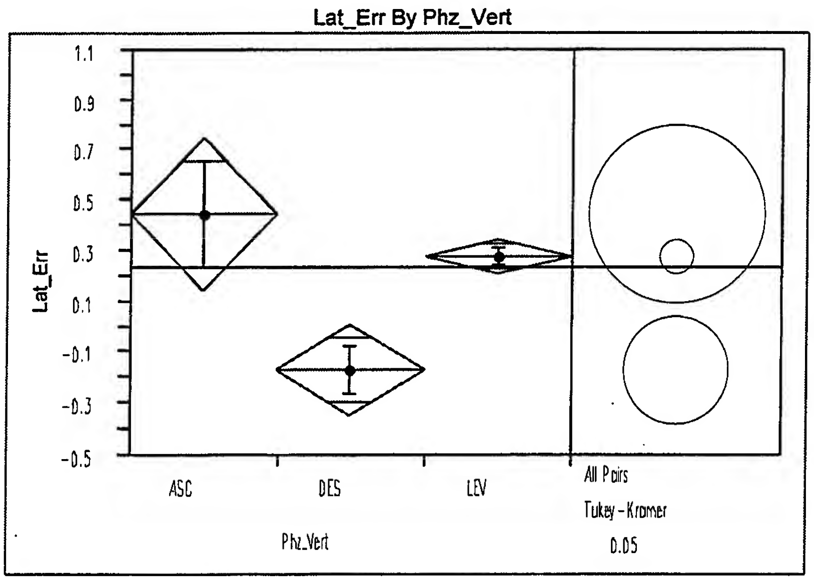
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 1014 | 5.813647 | 4.087130 | 3.937372 |
| DES | 2875 | 4.701637 | 3.268421 | 3.065992 |
| LEV | 17990 | 4.902850 | 3.396693 | 3.078998 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 6.1194 | 2 | 21876 | 0.0022 |
| Brown-Forsythe | 20.7468 | 2 | 21876 | <.0001 |
| Levene | 20.9098 | 2 | 21876 | <.0001 |
| Bartlett | 37.5879 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 109.0111 | 2 | 2259.5 | <.0001 |

**Figure A.2- 141 Statistical Tests for Horizontal Error and Vertical Phase of Flight at Look Ahead Time 600 for Samples at All Altitudes**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 1014 | 0.451527 | 6.73740 | 0.21158 |
| DES | 2875 | -0.17616 | 5.13148 | 0.09570 |
| LEV | 17990 | 0.289807 | 4.89881 | 0.03652 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | ASC | LEV | DES |
|---|---|---|---|
| ASC | 0.000000 | 0.161720 | 0.627690 |
| LEV | -0.16172 | 0.000000 | 0.465970 |
| DES | -0.62769 | -0.46597 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34386

| Abs(Dif)-LSD | ASC | LEV | DES |
|---|---|---|---|
| ASC | -0.52354 | -0.21877 | 0.197128 |
| LEV | -0.21877 | -0.1243 | 0.229198 |
| DES | 0.197128 | 0.229198 | -0.31092 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 1014 | 6.737396 | 3.656798 | 3.600371 |
| DES | 2875 | 5.131484 | 3.037528 | 3.028863 |
| LEV | 17990 | 4.898810 | 2.596783 | 2.543725 |

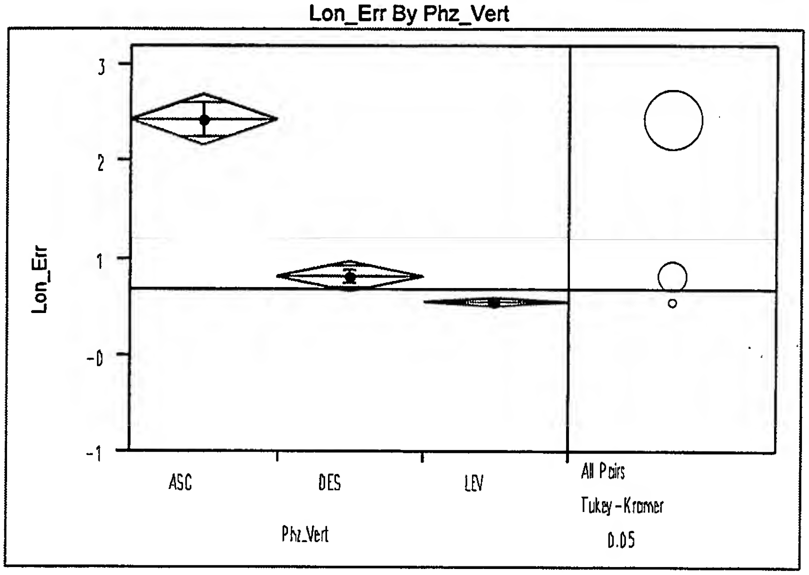
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 26.5479 | 2 | 21876 | <.0001 |
| Brown-Forsythe | 41.9461 | 2 | 21876 | <.0001 |
| Levene | 40.3832 | 2 | 21876 | <.0001 |
| Bartlett | 119.6425 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 10.8745 | 2 | 2211.1 | <.0001 |

**Figure A.2- 142 Statistical Tests for Lateral Error and Vertical Phase of Flight at Look Ahead Time 600 for Samples at All Altitudes**

Lon_Err By Phz_Vert




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 1014 | 2.03590 | 5.65689 | 0.17765 |
| DES | 2875 | 0.43200 | 4.42983 | 0.08262 |
| LEV | 17990 | 0.17391 | 4.32437 | 0.03224 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | ASC | DES | LEV |
|---|---|---|---|
| ASC | 0.00000 | 1.60389 | 1.86198 |
| DES | -1.60389 | 0.00000 | 0.25809 |
| LEV | -1.86198 | -0.25809 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34386

| Abs(Dif)-LSD | ASC | DES | LEV |
|---|---|---|---|
| ASC | -0.45893 | 1.22647 | 1.52845 |
| DES | 1.22647 | -0.27255 | 0.05054 |
| LEV | 1.52845 | 0.05054 | -0.10896 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

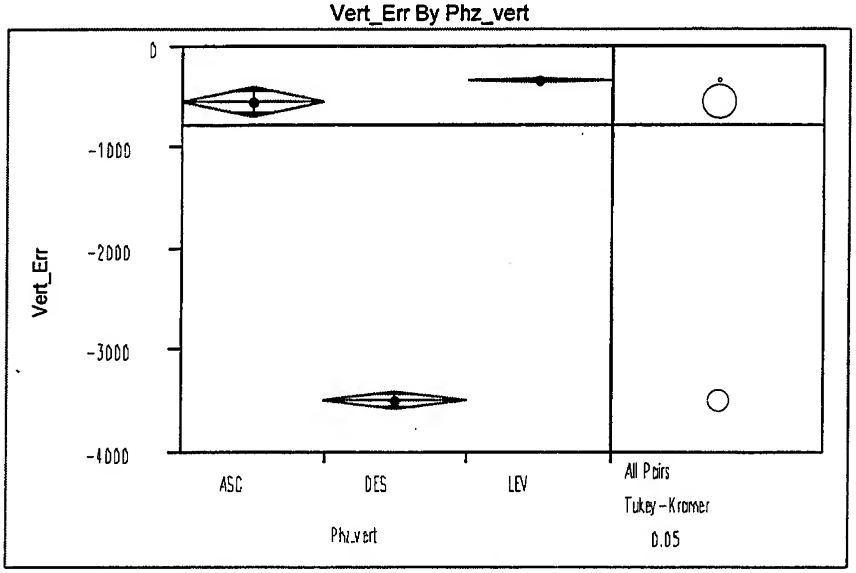
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 1014 | 5.656888 | 4.274895 | 4.269476 |
| DES | 2875 | 4.429833 | 2.968034 | 2.966377 |
| LEV | 17990 | 4.324370 | 2.691423 | 2.690756 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 15.8088 | 2 | 21876 | <.0001 |
| Brown-Forsythe | 108.0990 | 2 | 21876 | <.0001 |
| Levene | 108.8836 | 2 | 21876 | <.0001 |
| Bartlett | 81.5364 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 55.6820 | 2 | 2224.6 | <.0001 |

**Figure A.2- 143 Statistical Tests for Longitudinal Error and Vertical Phase of Flight at Look Ahead Time 600 for Samples at All Altitudes**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 1014 | -539.09 | 4371.02 | 137.27 |
| DES | 2875 | -3485.95 | 3520.40 | 65.66 |
| LEV | 17990 | -335.96 | 2325.02 | 17.33 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | LEV | ASC | DES |
|---|---|---|---|
| LEV | 0.00 | 203.13 | 3149.99 |
| ASC | -203.13 | 0.00 | 2946.86 |
| DES | -3149.99 | -2946.86 | 0.00 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34386

| Abs(Dif)-LSD | LEV | ASC | DES |
|---|---|---|---|
| LEV | -65.19 | 3.57 | 3025.81 |
| ASC | 3.57 | -274.58 | 2721.04 |
| DES | 3025.81 | 2721.04 | -163.07 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 1014 | 4371.022 | 3055.845 | 3004.434 |
| DES | 2875 | 3520.404 | 2667.354 | 2646.650 |
| LEV | 17990 | 2325.024 | 1222.506 | 1032.262 |

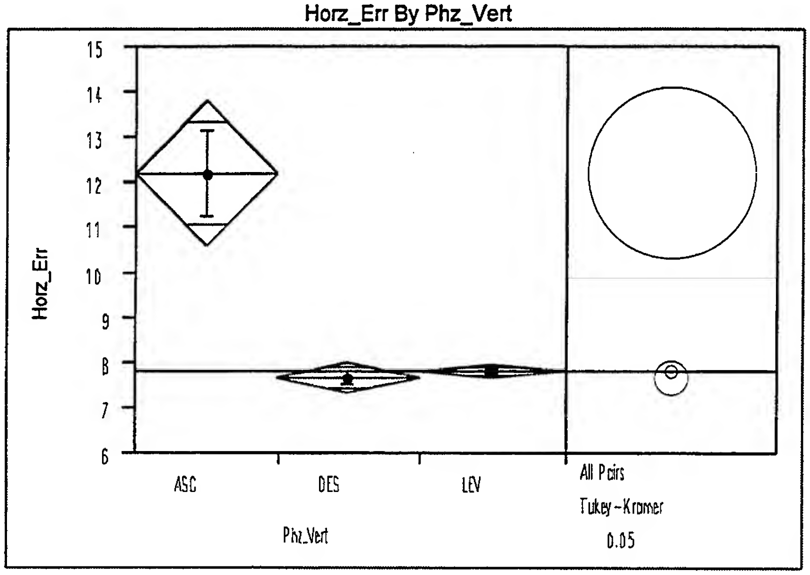
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 227.5370 | 2 | 21876 | <.0001 |
| Brown-Forsythe | 965.9416 | 2 | 21876 | 0.0000 |
| Levene | 889.3714 | 2 | 21876 | 0.0000 |
| Bartlett | 929.3615 | 2 | ? | 0.0000 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 1075.5693 | 2 | 2110.7 | 0.0000 |

**Figure A.2- 144 Statistical Tests for Vertical Error and Vertical Phase of Flight at Look Ahead Time 600 for Samples at All Altitudes**

Horz_Err By Phz_Vert




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 97 | 12.2024 | 9.49693 | 0.96427 |
| DES | 1855 | 7.6666 | 8.00219 | 0.18580 |
| LEV | 10954 | 7.8108 | 8.11594 | 0.07754 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | ASC | LEV | DES |
|---|---|---|---|
| ASC | 0.00000 | 4.39161 | 4.53580 |
| LEV | -4.39161 | 0.00000 | 0.14419 |
| DES | -4.53580 | -0.14419 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34397

| Abs(Dif)-LSD | ASC | LEV | DES |
|---|---|---|---|
| ASC | -2.72991 | 2.45274 | 2.55564 |
| LEV | 2.45274 | -0.25689 | -0.33313 |
| DES | 2.55564 | -0.33313 | -0.62426 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 97 | 9.496933 | 7.517472 | 7.247739 |
| DES | 1855 | 8.002193 | 5.154240 | 4.824625 |
| LEV | 10954 | 8.115937 | 5.901777 | 5.451606 |

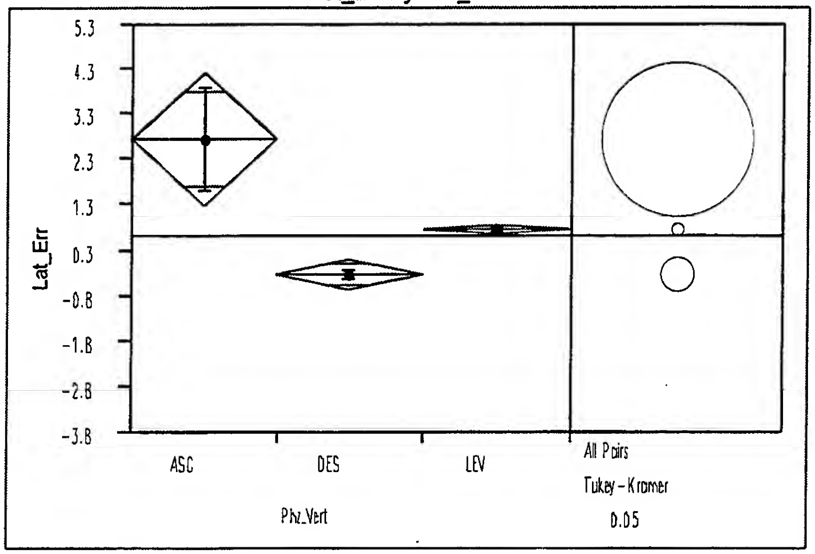
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 0.5803 | 2 | 12903 | 0.5598 |
| Brown-Forsythe | 10.8876 | 2 | 12903 | <.0001 |
| Levene | 18.3378 | 2 | 12903 | <.0001 |
| Bartlett | 2.9950 | 2 | ? | 0.0500 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 10.6430 | 2 | 249.29 | <.0001 |

**Figure A.2- 145 Statistical Tests for Horizontal Error and Vertical Phase of Flight at Look Ahead Time 1200 for Samples at All Altitudes**

Lat_Err By Phz_Vert




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 97 | 2.70167 | 11.5912 | 1.1769 |
| DES | 1855 | -0.29394 | 6.0832 | 0.1412 |
| LEV | 10954 | 0.68794 | 7.6128 | 0.0727 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | ASC | LEV | DES |
|---|---|---|---|
| ASC | 0.00000 | 2.01373 | 2.99561 |
| LEV | -2.01373 | 0.00000 | 0.98188 |
| DES | -2.99561 | -0.98188 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34397

| Abs(Dif)-LSD | ASC | LEV | DES |
|---|---|---|---|
| ASC | -2.50773 | 0.23266 | 1.17661 |
| LEV | 0.23266 | -0.23598 | 0.54340 |
| DES | 1.17661 | 0.54340 | -0.57345 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 97 | 11.59116 | 7.512274 | 6.667173 |
| DES | 1855 | 6.08316 | 3.632251 | 3.603511 |
| LEV | 10954 | 7.61284 | 4.116118 | 3.946437 |

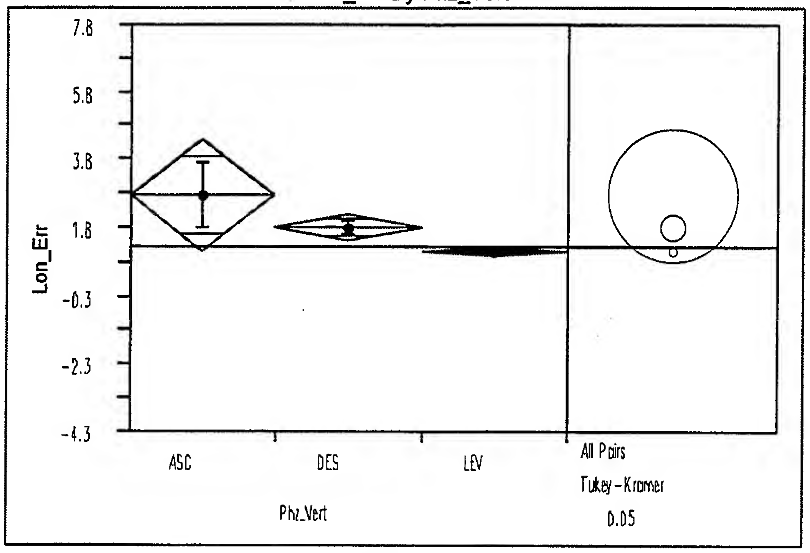
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 14.9438 | 2 | 12903 | <.0001 |
| Brown-Forsythe | 11.4096 | 2 | 12903 | <.0001 |
| Levene | 19.6871 | 2 | 12903 | <.0001 |
| Bartlett | 97.6154 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 20.8162 | 2 | 249.32 | <.0001 |

**Figure A.2- 146 Statistical Tests for Lateral Error and Vertical Phase of Flight at Look Ahead Time 1200 for Samples at All Altitudes**

Lon_Err By Phz_Vert




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 97 | 2.74775 | 9.55421 | 0.97008 |
| DES | 1855 | 1.74545 | 9.09419 | 0.21115 |
| LEV | 10954 | 1.09250 | 8.20124 | 0.07836 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | ASC | DES | LEV |
|---|---|---|---|
| ASC | 0.00000 | 1.00230 | 1.65525 |
| DES | -1.00230 | 0.00000 | 0.65296 |
| LEV | -1.65525 | -0.65296 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34397

| Abs(Dif)-LSD | ASC | DES | LEV |
|---|---|---|---|
| ASC | -2.80910 | -1.03531 | -0.33986 |
| DES | -1.03531 | -0.64236 | 0.16178 |
| LEV | -0.33986 | 0.16178 | -0.26434 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 97 | 9.554211 | 7.570830 | 7.564773 |
| DES | 1855 | 9.094186 | 5.574221 | 5.554658 |
| LEV | 10954 | 8.201244 | 5.388095 | 5.365922 |

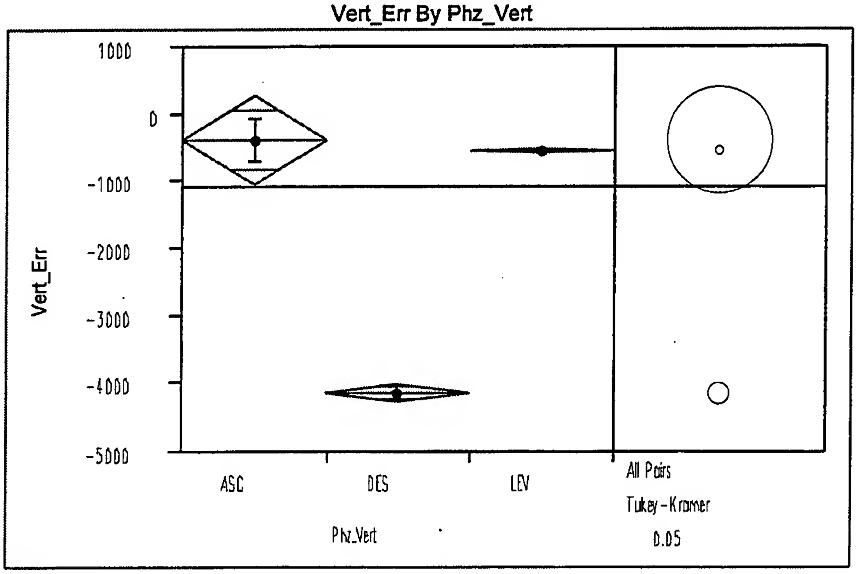
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 4.0377 | 2 | 12903 | 0.0177 |
| Brown-Forsythe | 6.2877 | 2 | 12903 | 0.0019 |
| Levene | 6.2617 | 2 | 12903 | 0.0019 |
| Bartlett | 19.6847 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 5.5004 | 2 | 248.83 | 0.0046 |

**Figure A.2- 147 Statistical Tests for Longitudinal Error and Vertical Phase of Flight at Look Ahead Time 1200 for Samples at All Altitudes**

Vert_Err By Phz_Vert




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 97 | -380.64 | 3302.06 | 335.27 |
| DES | 1855 | -4145.37 | 4589.18 | 106.55 |
| LEV | 10954 | -536.90 | 3093.46 | 29.56 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | ASC | LEV | DES |
|---|---|---|---|
| ASC | 0.00 | 156.26 | 3764.73 |
| LEV | -156.26 | 0.00 | 3608.47 |
| DES | -3764.73 | -3608.47 | 0.00 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34397

| Abs(Dif)-LSD | ASC | LEV | DES |
|---|---|---|---|
| ASC | -1127.93 | -644.83 | 2946.58 |
| LEV | -644.83 | -106.14 | 3411.25 |
| DES | 2946.58 | 3411.25 | -257.93 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 97 | 3302.064 | 2423.605 | 2407.041 |
| DES | 1855 | 4589.176 | 3334.635 | 3306.054 |
| LEV | 10954 | 3093.459 | 1740.157 | 1461.890 |

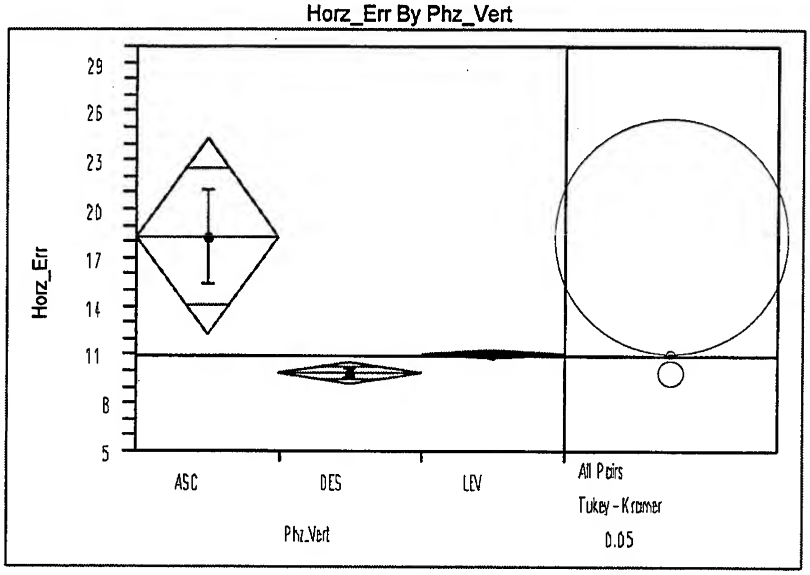
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 68.3927 | 2 | 12903 | <.0001 |
| Brown-Forsythe | 336.2527 | 2 | 12903 | <.0001 |
| Levene | 288.7853 | 2 | 12903 | <.0001 |
| Bartlett | 294.5648 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 531.8025 | 2 | 248.43 | <.0001 |

**Figure A.2- 148 Statistical Tests for Vertical Error and Vertical Phase of Flight at Look Ahead Time 1200 for Samples at All Altitudes**

Horz_Err By Phz_Vert




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 13 | 18.4117 | 10.8303 | 3.0038 |
| DES | 899 | 10.0099 | 10.1100 | 0.3372 |
| LEV | 5740 | 11.0734 | 11.3750 | 0.1501 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | ASC | LEV | DES |
|---|---|---|---|
| ASC | 0.00000 | 7.33828 | 8.40179 |
| LEV | -7.33828 | 0.00000 | 1.06351 |
| DES | -8.40179 | -1.06351 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34423

| Abs(Dif)-LSD | ASC | LEV | DES |
|---|---|---|---|
| ASC | -10.3087 | 0.0407 | 1.0599 |
| LEV | 0.0407 | -0.4906 | 0.1208 |
| DES | 1.0599 | 0.1208 | -1.2396 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 13 | 10.83032 | 7.995225 | 8.020500 |
| DES | 899 | 10.10995 | 6.983412 | 6.383636 |
| LEV | 5740 | 11.37495 | 8.383543 | 7.734759 |

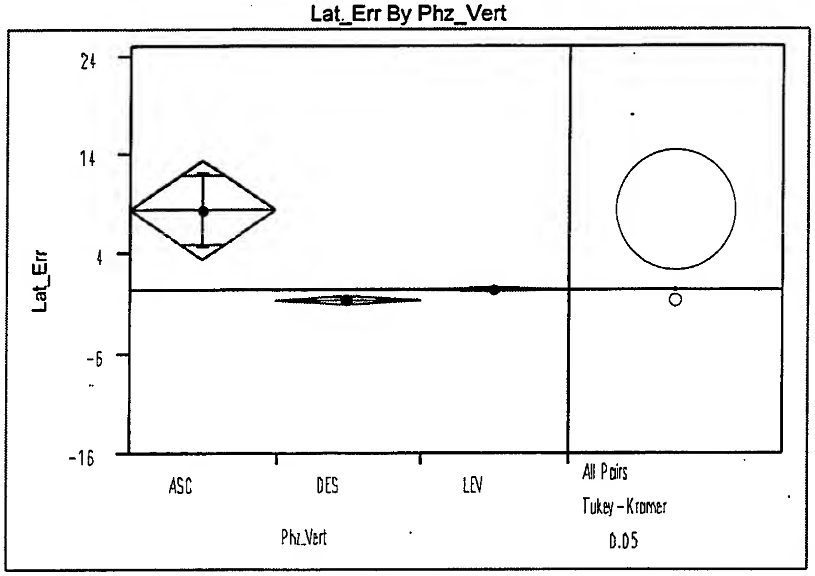
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 2.0972 | 2 | 6649 | 0.1229 |
| Brown-Forsythe | 8.4349 | 2 | 6649 | 0.0002 |
| Levene | 13.0717 | 2 | 6649 | <.0001 |
| Bartlett | 10.0616 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 7.1244 | 2 | 31.834 | 0.0028 |

**Figure A.2- 149 Statistical Tests for Horizontal Error and Vertical Phase of Flight at Look Ahead Time 1800 for Samples at All Altitudes**

Lat_Err By Phz_Vert




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 13 | 8.51086 | 13.9478 | 3.8684 |
| DES | 899 | -0.58525 | 7.8343 | 0.2613 |
| LEV | 5740 | 0.59977 | 9.5891 | 0.1266 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | ASC | LEV | DES |
|---|---|---|---|
| ASC | 0.00000 | 7.91109 | 9.09611 |
| LEV | -7.91109 | 0.00000 | 1.18501 |
| DES | -9.09611 | -1.18501 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34423

| Abs(Dif)-LSD | ASC | LEV | DES |
|---|---|---|---|
| ASC | -8.62586 | 1.80479 | 2.95276 |
| LEV | 1.80479 | -0.41050 | 0.39620 |
| DES | 2.95276 | 0.39620 | -1.03728 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 13 | 13.94780 | 11.74387 | 11.76735 |
| DES | 899 | 7.83429 | 4.67286 | 4.55423 |
| LEV | 5740 | 9.58914 | 5.03219 | 4.90163 |

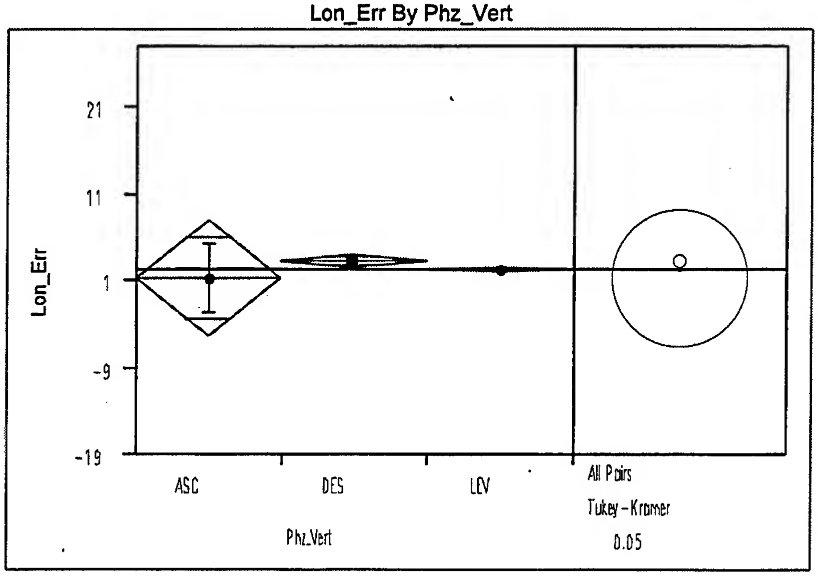
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 3.4555 | 2 | 6649 | 0.0316 |
| Brown-Forsythe | 5.5253 | 2 | 6649 | 0.0040 |
| Levene | 5.5092 | 2 | 6649 | 0.0041 |
| Bartlett | 30.8193 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 10.3232 | 2 | 31.774 | 0.0004 |

**Figure A.2- 150 Statistical Tests for Lateral Error and Vertical Phase of Flight at Look Ahead Time 1800 for Samples at All Altitudes**

Lon_Err By Phz_Vert




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 13 | 1.44341 | 14.4660 | 4.0122 |
| DES | 899 | 3.23863 | 11.4150 | 0.3807 |
| LEV | 5740 | 2.30849 | 12.4254 | 0.1640 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | DES | LEV | ASC |
|---|---|---|---|
| DES | 0.00000 | 0.93013 | 1.79522 |
| LEV | -0.93013 | 0.00000 | 0.86509 |
| ASC | -1.79522 | -0.86509 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34423

| Abs(Dif)-LSD | DES | LEV | ASC |
|---|---|---|---|
| DES | -1.3598 | -0.1039 | -6.2581 |
| LEV | -0.1039 | -0.5381 | -7.1397 |
| ASC | -6.2581 | -7.1397 | -11.3076 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

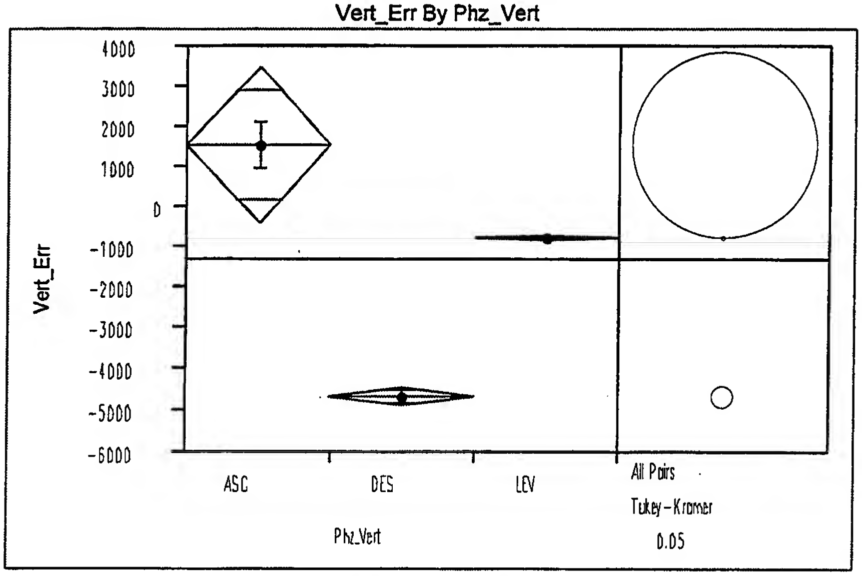
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 13 | 14.46603 | 11.37245 | 11.36032 |
| DES | 899 | 11.41499 | 7.49707 | 7.37398 |
| LEV | 5740 | 12.42540 | 8.27380 | 8.15128 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 1.5218 | 2 | 6649 | 0.2184 |
| Brown-Forsythe | 3.4678 | 2 | 6649 | 0.0312 |
| Levene | 3.5718 | 2 | 6649 | 0.0282 |
| Bartlett | 5.6347 | 2 | ? | 0.0036 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 2.4966 | 2 | 31.785 | 0.0984 |

**Figure A.2- 151 Statistical Tests for Longitudinal Error and Vertical Phase of Flight at Look Ahead Time 1800 for Samples at All Altitudes**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 13 | 1569.38 | 2217.34 | 614.98 |
| DES | 899 | -4666.23 | 4881.61 | 162.81 |
| LEV | 5740 | -741.66 | 3393.31 | 44.79 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | ASC | LEV | DES |
|---|---|---|---|
| ASC | 0.00 | 2311.05 | 6235.62 |
| LEV | -2311.05 | 0.00 | 3924.57 |
| DES | -6235.62 | -3924.57 | 0.00 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34423

| Abs(Dif)-LSD | ASC | LEV | DES |
|---|---|---|---|
| ASC | -3336.33 | -50.77 | 3859.48 |
| LEV | -50.77 | -158.78 | 3619.47 |
| DES | 3859.48 | 3619.47 | -401.20 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

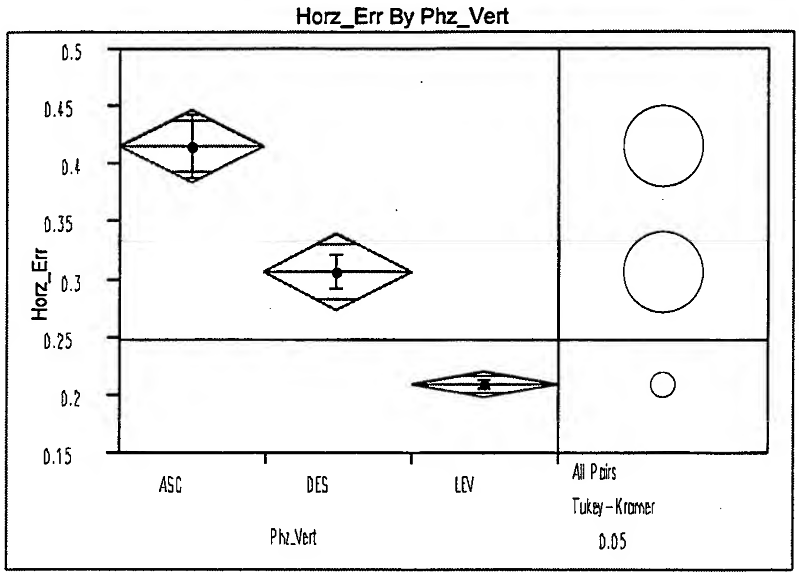
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 13 | 2217.340 | 1651.030 | 1617.077 |
| DES | 899 | 4881.614 | 3663.617 | 3614.791 |
| LEV | 5740 | 3393.309 | 2069.711 | 1699.630 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 38.2003 | 2 | 6649 | <.0001 |
| Brown-Forsythe | 151.0714 | 2 | 6649 | <.0001 |
| Levene | 129.4422 | 2 | 6649 | <.0001 |
| Bartlett | 122.3683 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 273.1920 | 2 | 31.943 | <.0001 |

**Figure A.2- 152 Statistical Tests for Vertical Error and Vertical Phase of Flight at Look Ahead Time 1800 for Samples at All Altitudes**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 2202 | 0.422096 | 1.34263 | 0.02861 |
| DES | 1812 | 0.306551 | 0.69023 | 0.01621 |
| LEV | 17151 | 0.220674 | 0.64413 | 0.00492 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | ASC | DES | LEV |
|---|---|---|---|
| ASC | 0.000000 | 0.115545 | 0.201422 |
| DES | -0.11554 | 0.000000 | 0.085878 |
| LEV | -0.20142 | -0.08588 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34387

| Abs(Dif)-LSD | ASC | DES | LEV |
|---|---|---|---|
| ASC | -0.05307 | 0.059689 | 0.161558 |
| DES | 0.059689 | -0.05851 | 0.042377 |
| LEV | 0.161558 | 0.042377 | -0.01902 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

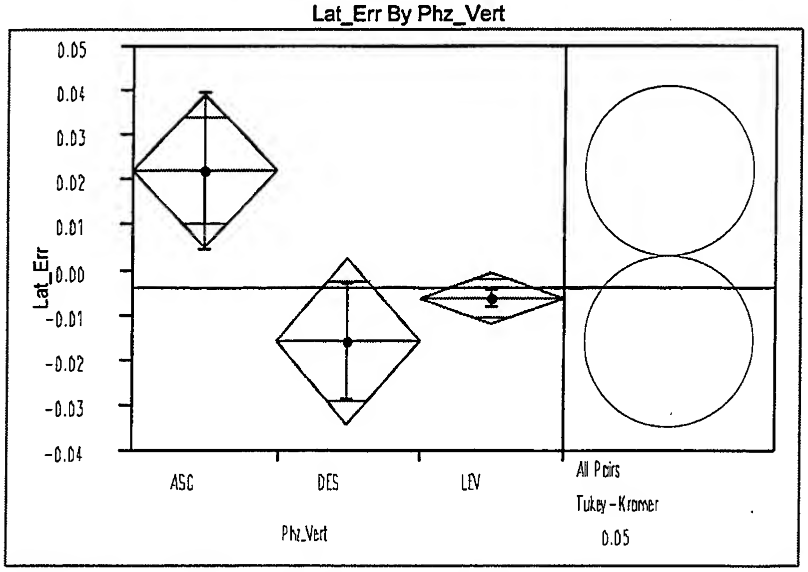
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 2202 | 1.342634 | 0.4169606 | 0.3333033 |
| DES | 1812 | 0.690227 | 0.2575815 | 0.2205308 |
| LEV | 17151 | 0.644126 | 0.1764805 | 0.1506448 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 4.6705 | 2 | 21162 | 0.0094 |
| Brown-Forsythe | 63.2918 | 2 | 21162 | <.0001 |
| Levene | 114.1045 | 2 | 21162 | <.0001 |
| Bartlett | 1515.9052 | 2 | ? | 0.0000 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 35.2595 | 2 | 2973.9 | <.0001 |

**Figure A.2- 153 Statistical Tests for Horizontal Error and Vertical Phase of Flight at Look Ahead Time 0 for Samples at Altitudes Above 18,000 Feet**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 2202 | 0.024691 | 0.840207 | 0.01791 |
| DES | 1812 | -0.01042 | 0.548250 | 0.01288 |
| LEV | 17151 | -0.00357 | 0.294129 | 0.00225 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | ASC | LEV | DES |
|---|---|---|---|
| ASC | 0.000000 | 0.028265 | 0.035107 |
| LEV | -0.02826 | 0.000000 | 0.006843 |
| DES | -0.03511 | -0.00684 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34387

| Abs(Dif)-LSD | ASC | LEV | DES |
|---|---|---|---|
| ASC | -0.02906 | 0.006436 | 0.004522 |
| LEV | 0.006436 | -0.01041 | -0.01698 |
| DES | 0.004522 | -0.01698 | -0.03204 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

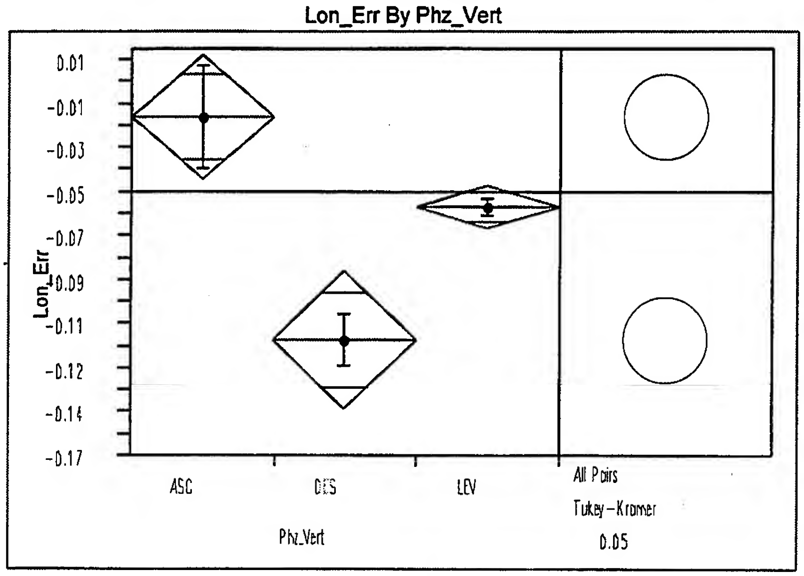
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 2202 | 0.8402071 | 0.1928937 | 0.1879958 |
| DES | 1812 | 0.5482501 | 0.1592899 | 0.1585052 |
| LEV | 17151 | 0.2941291 | 0.0938289 | 0.0936644 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 16.2492 | 2 | 21162 | <.0001 |
| Brown-Forsythe | 71.0257 | 2 | 21162 | <.0001 |
| Levene | 76.9380 | 2 | 21162 | <.0001 |
| Bartlett | 3662.7047 | 2 | ? | 0.0000 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 1.3815 | 2 | 2773.6 | 0.2514 |

**Figure A.2- 154 Statistical Tests for Lateral Error and Vertical Phase of Flight at Look Ahead Time 0 for Samples at Altitudes Above 18,000 Feet**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 2202 | -0.01037 | 1.12883 | 0.02406 |
| DES | 1812 | -0.09327 | 0.51093 | 0.01200 |
| LEV | 17151 | -0.04388 | 0.61249 | 0.00468 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | ASC | LEV | DES |
|---|---|---|---|
| ASC | 0.000000 | 0.033507 | 0.082895 |
| LEV | -0.03351 | 0.000000 | 0.049388 |
| DES | -0.08289 | -0.04939 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34387

| Abs(Dif)-LSD | ASC | LEV | DES |
|---|---|---|---|
| ASC | -0.04785 | -0.00244 | 0.032534 |
| LEV | -0.00244 | -0.01715 | 0.010167 |
| DES | 0.032534 | 0.010167 | -0.05275 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 2202 | 1.128826 | 0.3302633 | 0.3275759 |
| DES | 1812 | 0.510930 | 0.2119499 | 0.2104763 |
| LEV | 17151 | 0.612493 | 0.1669001 | 0.1668973 |

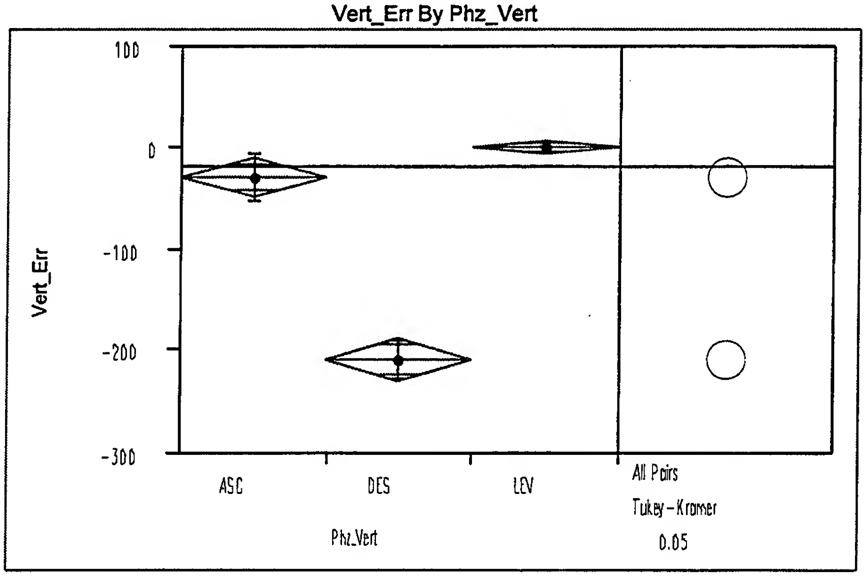
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 2.4500 | 2 | 21162 | 0.0863 |
| Brown-Forsythe | 61.0119 | 2 | 21162 | <.0001 |
| Levene | 63.2115 | 2 | 21162 | <.0001 |
| Bartlett | 1114.5912 | 2 | ? | 0.0000 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 8.6873 | 2 | 3146 | 0.0002 |

**Figure A.2- 155 Statistical Tests for Longitudinal Error and Vertical Phase of Flight at Look Ahead Time 0 for Samples at Altitudes Above 18,000 Feet**

Vert_Err By Phz_Vert




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 2202 | -23.475 | 1123.64 | 23.945 |
| DES | 1812 | -202.305 | 833.07 | 19:570 |
| LEV | 17151 | 2.754 | 263.21 | 2.010 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | LEV | ASC | DES |
|---|---|---|---|
| LEV | 0.000 | 26.229 | 205.059 |
| ASC | -26.229 | 0.000 | 178.830 |
| DES | -205.059 | -178.830 | 0.000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34387

| Abs(Dif)-LSD | LEV | ASC | DES |
|---|---|---|---|
| LEV | -12.575 | -0.132 | 176.293 |
| ASC | -0.132 | -35.096 | 141.893 |
| DES | 176.293 | 141.893 | -38.689 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 2202 | 1123.636 | 254.6128 | 250.7931 |
| DES | 1812 | 833.068 | 252.5226 | 227.5891 |
| LEV | 17151 | 263.211 | 32.9780 | 30.8177 |

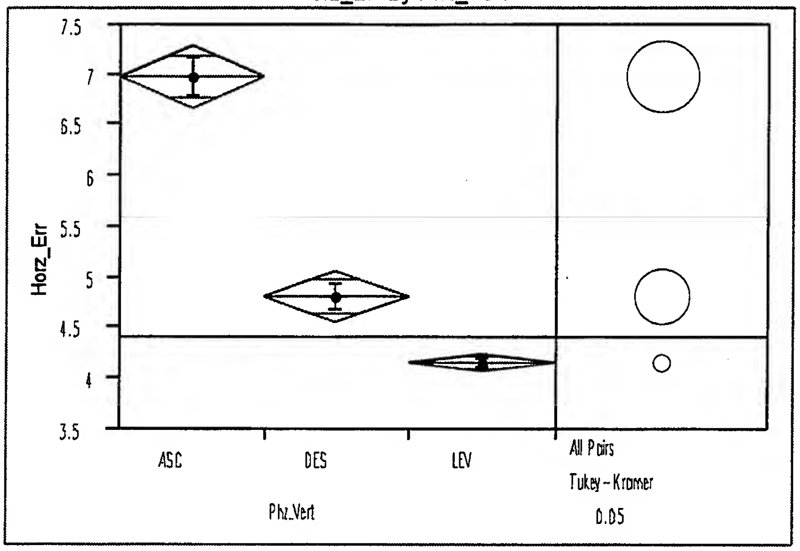
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 36.6913 | 2 | 21162 | <.0001 |
| Brown-Forsythe | 303.4953 | 2 | 21162 | <.0001 |
| Levene | 338.8610 | 2 | 21162 | <.0001 |
| Bartlett | 8162.1553 | 2 | ? | 0.0000 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 54.8100 | 2 | 2696.6 | <.0001 |

**Figure A.2- 156 Statistical Tests for Vertical Error and Vertical Phase of Flight at Look Ahead Time 0 for Samples at Altitudes Above 18,000 Feet**

Horz_Err By Phz_Vert




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 945 | 6.98980 | 5.93362 | 0.19302 |
| DES | 1540 | 4.82235 | 5.21500 | 0.13289 |
| LEV | 12296 | 4.16374 | 5.02739 | 0.04534 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | ASC | DES | LEV |
|---|---|---|---|
| ASC | 0.00000 | 2.16744 | 2.82605 |
| DES | -2.16744 | 0.00000 | 0.65861 |
| LEV | -2.82605 | -0.65861 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34394

| Abs(Dif)-LSD | ASC | DES | LEV |
|---|---|---|---|
| ASC | -0.55099 | 1.67253 | 2.42175 |
| DES | 1.67253 | -0.43162 | 0.33486 |
| LEV | 2.42175 | 0.33486 | -0.15275 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 945 | 5.933623 | 4.162648 | 3.996077 |
| DES | 1540 | 5.214998 | 3.500156 | 3.204339 |
| LEV | 12296 | 5.027388 | 3.389343 | 3.017383 |

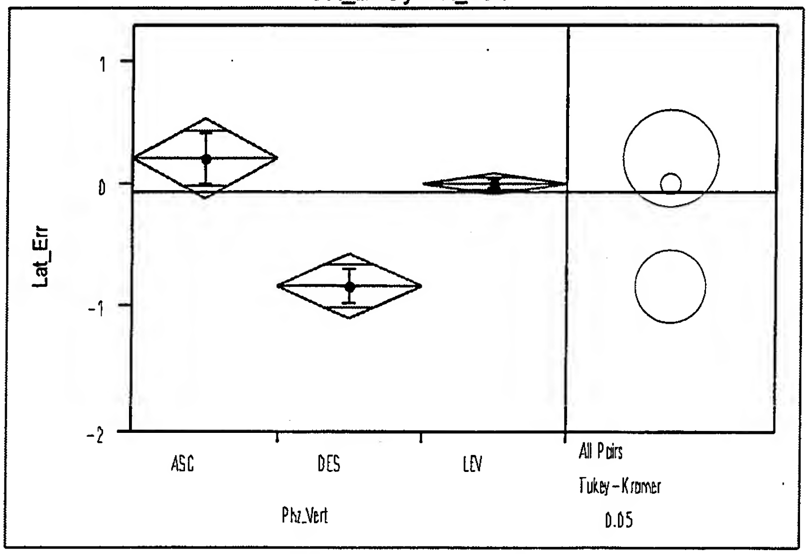
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 4.4606 | 2 | 14778 | 0.0116 |
| Brown-Forsythe | 22.0580 | 2 | 14778 | <.0001 |
| Levene | 18.6727 | 2 | 14778 | <.0001 |
| Bartlett | 27.2158 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 108.1923 | 2 | 1788.8 | <.0001 |

**Figure A.2- 157 Statistical Tests for Horizontal Error and Vertical Phase of Flight at Look Ahead Time 600 for Samples at Altitudes Above 18,000 Feet**

Lat_Err By Phz_Vert




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 945 | 0.628674 | 6.83593 | 0.22237 |
| DES | 1540 | -0.41593 | 5.77308 | 0.14711 |
| LEV | 12296 | 0.398568 | 5.17147 | 0.04664 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | ASC | LEV | DES |
|---|---|---|---|
| ASC | 0.00000 | 0.23011 | 1.04460 |
| LEV | -0.23011 | 0.00000 | 0.81449 |
| DES | -1.04460 | -0.81449 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34394

| Abs(Dif)-LSD | ASC | LEV | DES |
|---|---|---|---|
| ASC | -0.57774 | -0.19383 | 0.525653 |
| LEV | -0.19383 | -0.16017 | 0.475026 |
| DES | 0.525653 | 0.475026 | -0.45257 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 945 | 6.835927 | 3.704871 | 3.608629 |
| DES | 1540 | 5.773082 | 3.412944 | 3.373358 |
| LEV | 12296 | 5.171465 | 2.675225 | 2.574678 |

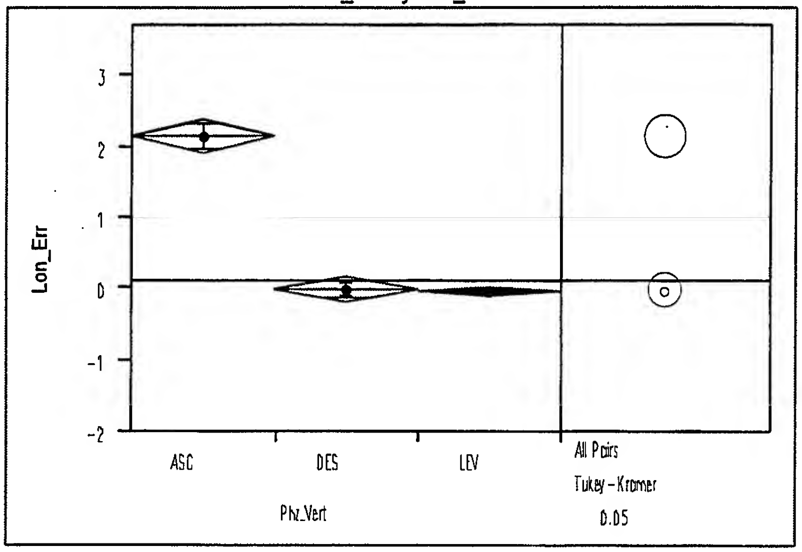
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 17.9586 | 2 | 14778 | <.0001 |
| Brown-Forsythe | 38.9748 | 2 | 14778 | <.0001 |
| Levene | 37.2465 | 2 | 14778 | <.0001 |
| Bartlett | 90.4058 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 14.8229 | 2 | 1752.7 | <.0001 |

**Figure A.2- 158 Statistical Tests for Lateral Error and Vertical Phase of Flight at Look Ahead Time 600 for Samples at Altitudes Above 18,000 Feet**

Lon_Err By Phz_Vert




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 945 | 2.34529 | 5.61116 | 0.18253 |
| DES | 1540 | 0.19763 | 4.11409 | 0.10484 |
| LEV | 12296 | 0.17573 | 3.95967 | 0.03571 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | ASC | DES | LEV |
|---|---|---|---|
| ASC | 0.00000 | 2.14766 | 2.16956 |
| DES | -2.14766 | 0.00000 | 0.02190 |
| LEV | -2.16956 | -0.02190 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34394

| Abs(Dif)-LSD | ASC | DES | LEV |
|---|---|---|---|
| ASC | -0.44222 | 1.75045 | 1.84507 |
| DES | 1.75045 | -0.34641 | -0.23794 |
| LEV | 1.84507 | -0.23794 | -0.12259 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

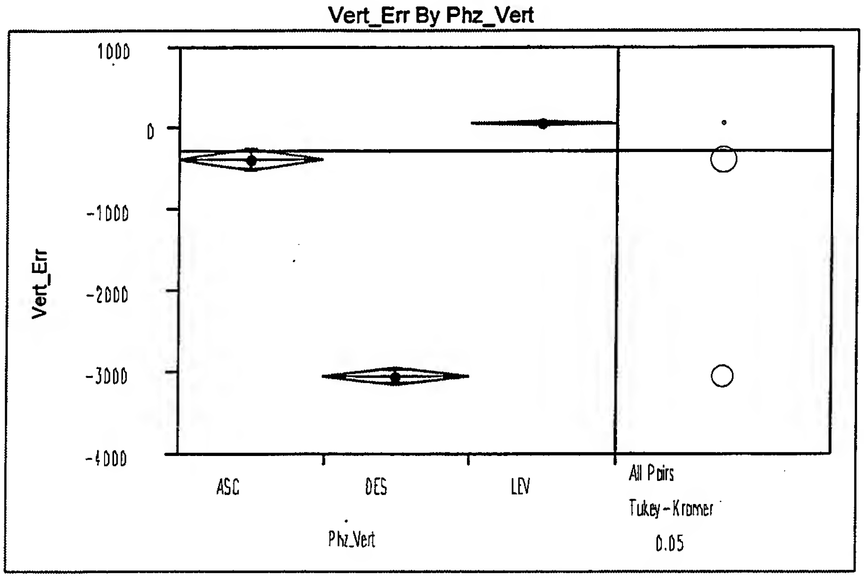
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 945 | 5.611159 | 4.188685 | 4.184091 |
| DES | 1540 | 4.114089 | 2.545280 | 2.544765 |
| LEV | 12296 | 3.959669 | 2.435704 | 2.433590 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 24.6430 | 2 | 14778 | <.0001 |
| Brown-Forsythe | 133.0151 | 2 | 14778 | <.0001 |
| Levene | 133.7116 | 2 | 14778 | <.0001 |
| Bartlett | 130.4081 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 68.1467 | 2 | 1757.4 | <.0001 |

**Figure A.2- 159 Statistical Tests for Longitudinal Error and Vertical Phase of Flight at Look Ahead Time 600 for Samples at Altitudes Above 18,000 Feet**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 945 | -380.28 | 4319.61 | 140.52 |
| DES | 1540 | -3032.69 | 3379.09 | 86.11 |
| LEV | 12296 | 65.83 | 2043.03 | 18.42 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | LEV | ASC | DES |
|---|---|---|---|
| LEV | 0.00 | 446.11 | 3098.52 |
| ASC | -446.11 | 0.00 | 2652.41 |
| DES | -3098.52 | -2652.41 | 0.00 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34394

| Abs(Dif)-LSD | LEV | ASC | DES |
|---|---|---|---|
| LEV | -72.33 | 254.67 | 2945.23 |
| ASC | 254.67 | -260.89 | 2418.07 |
| DES | 2945.23 | 2418.07 | -204.37 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 945 | 4319.607 | 3002.328 | 2940.678 |
| DES | 1540 | 3379.094 | 2559.165 | 2542.165 |
| LEV | 12296 | 2043.027 | 779.610 | 737.421 |

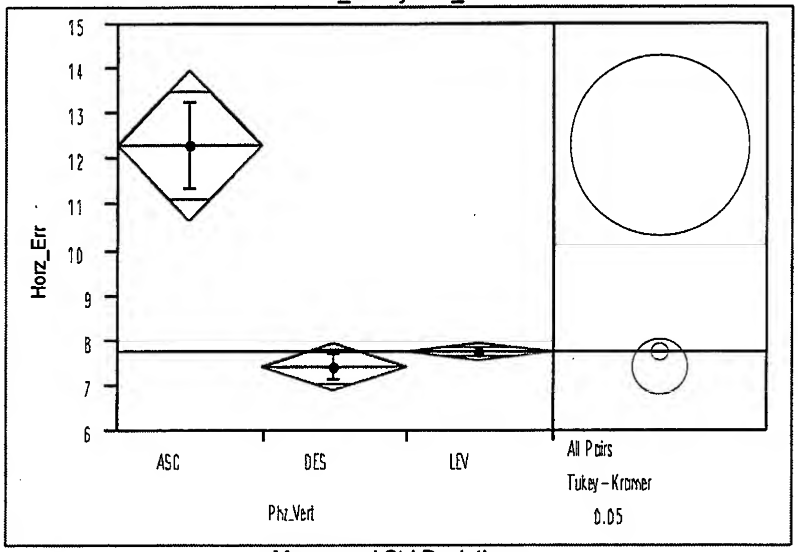
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 186.7679 | 2 | 14778 | <.0001 |
| Brown-Forsythe | 948.1531 | 2 | 14778 | 0.0000 |
| Levene | 973.3493 | 2 | 14778 | 0.0000 |
| Bartlett | 1017.5161 | 2 | ? | 0.0000 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 621.2446 | 2 | 1645.5 | <.0001 |

**Figure A.2- 160 Statistical Tests for Vertical Error and Vertical Phase of Flight at Look Ahead Time 600 for Samples at Altitudes Above 18,000 Feet**

Horz_Err By Phz_Vert




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 95 | 12.3169 | 9.55293 | 0.98011 |
| DES | 856 | 7.4245 | 8.55565 | 0.29243 |
| LEV | 7223 | 7.7775 | 8.38689 | 0.09868 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | ASC | LEV | DES |
|---|---|---|---|
| ASC | 0.00000 | 4.53939 | 4.89236 |
| LEV | -4.53939 | 0.00000 | 0.35297 |
| DES | -4.89236 | -0.35297 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34413

| Abs(Dif)-LSD | ASC | LEV | DES |
|---|---|---|---|
| ASC | -2.86349 | 2.50132 | 2.75817 |
| LEV | 2.50132 | -0.32840 | -0.36042 |
| DES | 2.75817 | -0.36042 | -0.95394 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

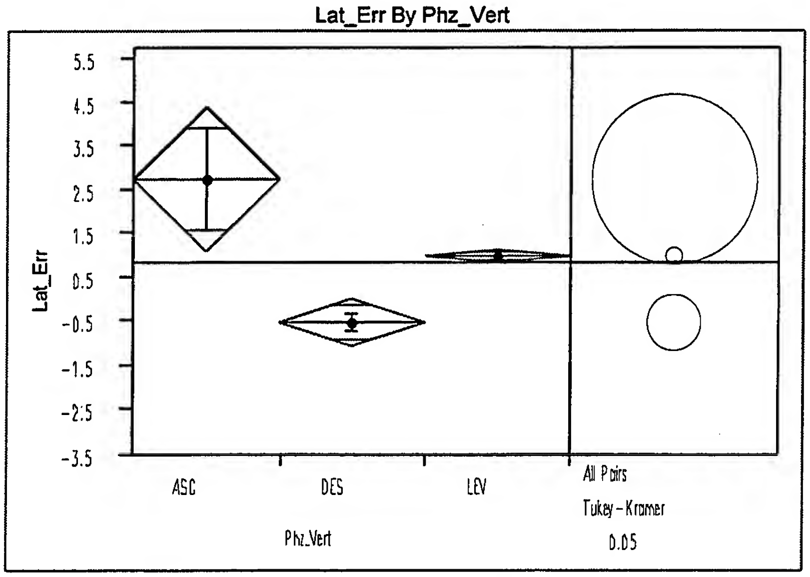
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 95 | 9.552931 | 7.586070 | 7.334192 |
| DES | 856 | 8.555648 | 5.319627 | 4.889017 |
| LEV | 7223 | 8.386888 | 6.017697 | 5.509816 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 0.4071 | 2 | 8171 | 0.6656 |
| Brown-Forsythe | 6.3817 | 2 | 8171 | 0.0017 |
| Levene | 8.8861 | 2 | 8171 | 0.0001 |
| Bartlett | 1.9610 | 2 | ? | 0.1407 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 11.4198 | 2 | 234.05 | <.0001 |

**Figure A.2- 161 Statistical Tests for Horizontal Error and Vertical Phase of Flight at Look Ahead Time 1200 for Samples at Altitudes Above 18,000 Feet**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 95 | 2.78727 | 11.6949 | 1.1999 |
| DES | 856 | -0.51335 | 6.5813 | 0.2249 |
| LEV | 7223 | 1.00169 | 8.3609 | 0.0984 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | ASC | LEV | DES |
|---|---|---|---|
| ASC | 0.00000 | 1.78558 | 3.30063 |
| LEV | -1.78558 | 0.00000 | 1.51504 |
| DES | -3.30063 | -1.51504 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34413

| Abs(Dif)-LSD | ASC | LEV | DES |
|---|---|---|---|
| ASC | -2.80247 | -0.20905 | 1.21191 |
| LEV | -0.20905 | -0.32140 | 0.81686 |
| DES | 1.21191 | 0.81686 | -0.93361 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 95 | 11.69487 | 7.620599 | 6.765580 |
| DES | 856 | 6.58134 | 3.961623 | 3.888615 |
| LEV | 7223 | 8.36086 | 4.579453 | 4.285086 |

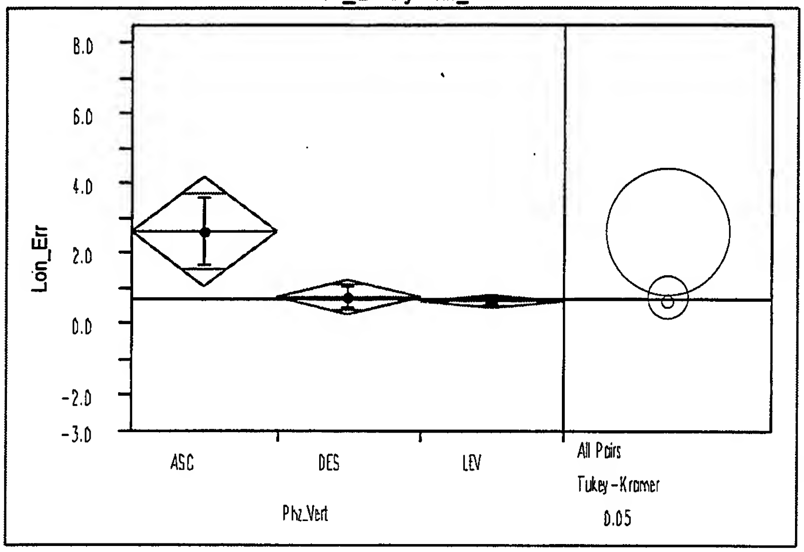
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 8.2021 | 2 | 8171 | 0.0003 |
| Brown-Forsythe | 7.1040 | 2 | 8171 | 0.0008 |
| Levene | 12.7391 | 2 | 8171 | <.0001 |
| Bartlett | 53.5887 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 20.4032 | 2 | 234.97 | <.0001 |

**Figure A.2- 162 Statistical Tests for Lateral Error and Vertical Phase of Flight at Look Ahead Time 1200 for Samples at Altitudes Above 18,000 Feet**

Lon_Err By Phz_Vert




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 95 | 2.71589 | 9.61780 | 0.98677 |
| DES | 856 | 0.81066 | 9.17341 | 0.31354 |
| LEV | 7223 | 0.67125 | 7.71231 | 0.09075 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | ASC | DES | LEV |
|---|---|---|---|
| ASC | 0.00000 | 1.90524 | 2.04465 |
| DES | -1.90524 | 0.00000 | 0.13941 |
| LEV | -2.04465 | -0.13941 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34413

| Abs(Dif)-LSD | ASC | DES | LEV |
|---|---|---|---|
| ASC | -2.68763 | -0.09789 | 0.13175 |
| DES | -0.09789 | -0.89535 | -0.53017 |
| LEV | 0.13175 | -0.53017 | -0.30823 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

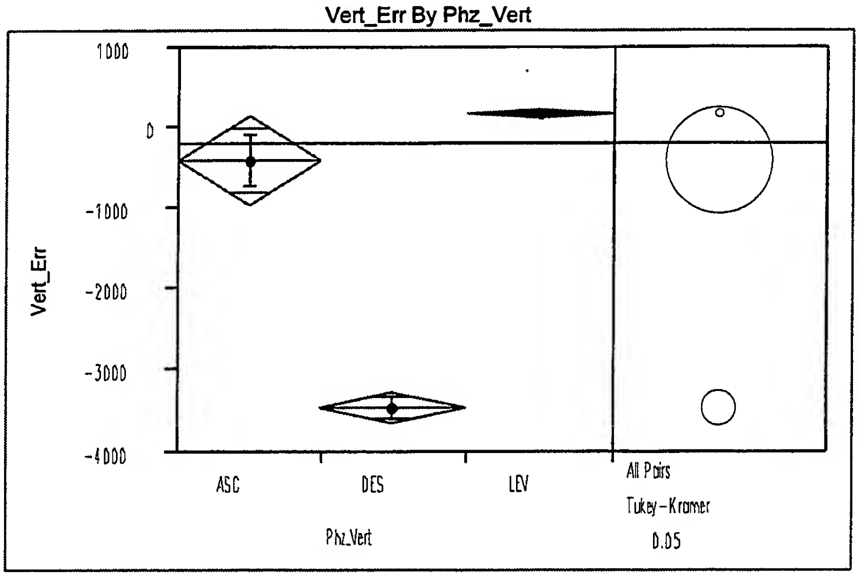
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 95 | 9.617799 | 7.612791 | 7.605600 |
| DES | 856 | 9.173409 | 5.150617 | 5.127945 |
| LEV | 7223 | 7.712305 | 5.014171 | 5.002155 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 6.3232 | 2 | 8171 | 0.0018 |
| Brown-Forsythe | 8.6664 | 2 | 8171 | 0.0002 |
| Levene | 8.7217 | 2 | 8171 | 0.0002 |
| Bartlett | 29.3676 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 2.1926 | 2 | 232.44 | 0.1139 |

**Figure A.2- 163 Statistical Tests for Longitudinal Error and Vertical Phase of Flight at Look Ahead Time 1200 for Samples at Altitudes Above 18,000 Feet**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 95 | -408.74 | 3331.19 | 341.77 |
| DES | 856 | -3460.70 | 4468.07 | 152.72 |
| LEV | 7223 | 187.36 | 2589.29 | 30.47 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | LEV | ASC | DES |
|---|---|---|---|
| LEV | 0.00 | 596.09 | 3648.06 |
| ASC | -596.09 | 0.00 | 3051.96 |
| DES | -3648.06 | -3051.96 | 0.00 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34413

| Abs(Dif)-LSD | LEV | ASC | DES |
|---|---|---|---|
| LEV | -111.30 | -94.68 | 3406.27 |
| ASC | -94.68 | -970.53 | 2328.61 |
| DES | 3406.27 | 2328.61 | -323.32 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

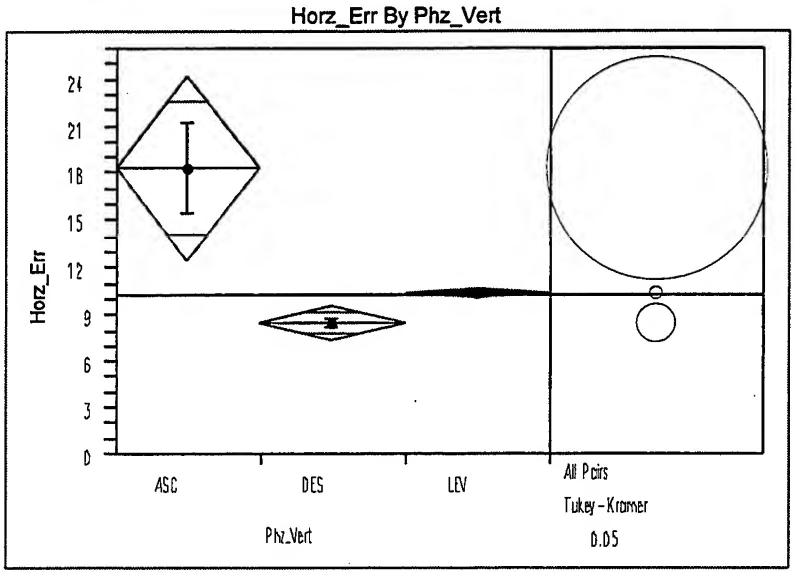
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 95 | 3331.191 | 2442.988 | 2422.905 |
| DES | 856 | 4468.066 | 3173.108 | 3159.027 |
| LEV | 7223 | 2589.291 | 1099.377 | 974.838 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 48.6677 | 2 | 8171 | <.0001 |
| Brown-Forsythe | 303.9437 | 2 | 8171 | <.0001 |
| Levene | 286.5383 | 2 | 8171 | <.0001 |
| Bartlett | 303.1262 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 274.4881 | 2 | 230.68 | <.0001 |

**Figure A.2- 164 Statistical Tests for Vertical Error and Vertical Phase of Flight at Look Ahead Time 1200 for Samples at Altitudes Above 18,000 Feet**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 13 | 18.4117 | 10.8303 | 3.0038 |
| DES | 392 | 8.5610 | 7.7092 | 0.3894 |
| LEV | 3507 | 10.5180 | 11.3798 | 0.1922 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | ASC | LEV | DES |
|---|---|---|---|
| ASC | 0.00000 | 7.89373 | 9.85070 |
| LEV | -7.89373 | 0.00000 | 1.95697 |
| DES | -9.85070 | -1.95697 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34460

| Abs(Dif)-LSD | ASC | LEV | DES |
|---|---|---|---|
| ASC | -10.1765 | 0.6846 | 2.5365 |
| LEV | 0.6846 | -0.6196 | 0.5753 |
| DES | 2.5365 | 0.5753 | -1.8532 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

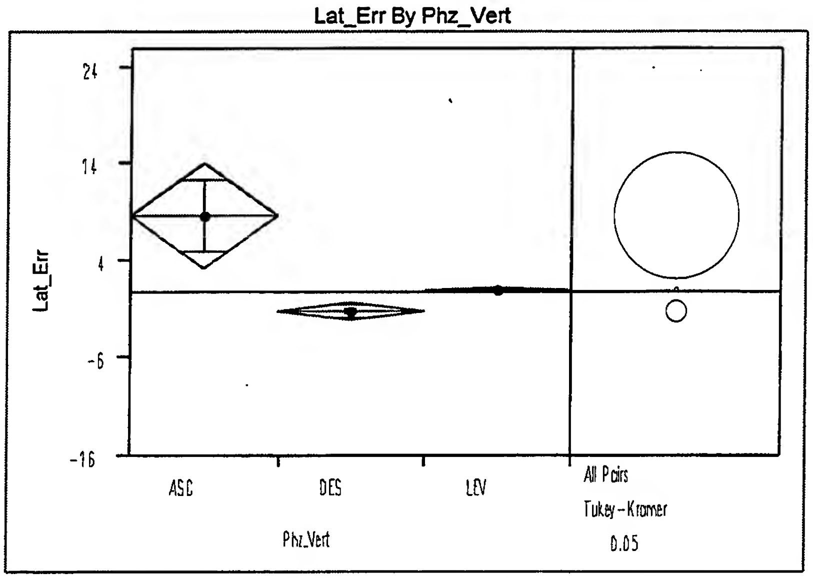
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 13 | 10.83032 | 7.995225 | 8.020500 |
| DES | 392 | 7.70925 | 5.455350 | 5.193106 |
| LEV | 3507 | 11.37979 | 8.106691 | 7.402555 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 6.1623 | 2 | 3909 | 0.0021 |
| Brown-Forsythe | 10.1909 | 2 | 3909 | <.0001 |
| Levene | 20.5557 | 2 | 3909 | <.0001 |
| Bartlett | 42.8970 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 13.6521 | 2 | 31.575 | <.0001 |

**Figure A.2- 165 Statistical Tests for Horizontal Error and Vertical Phase of Flight at Look Ahead Time 1800 for Samples at Altitudes Above 18,000 Feet**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 13 | 8.51086 | 13.9478 | 3.8684 |
| DES | 392 | -1.33389 | 8.2139 | 0.4149 |
| LEV | 3507 | 0.90741 | 10.4962 | 0.1772 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | ASC | LEV | DES |
|---|---|---|---|
| ASC | 0.00000 | 7.60345 | 9.84475 |
| LEV | -7.60345 | 0.00000 | 2.24130 |
| DES | -9.84475 | -2.24130 | 0.00000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34460

| Abs(Dif)-LSD | ASC | LEV | DES |
|---|---|---|---|
| ASC | -9.47522 | 0.89105 | 3.03457 |
| LEV | 0.89105 | -0.57689 | 0.95480 |
| DES | 3.03457 | 0.95480 | -1.72551 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

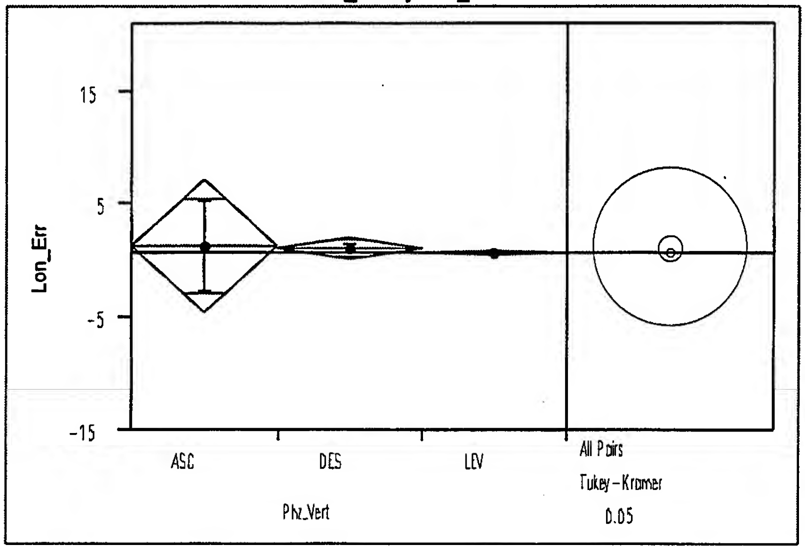
| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 13 | 13.94780 | 11.74387 | 11.76735 |
| DES | 392 | 8.21390 | 5.21613 | 4.93337 |
| LEV | 3507 | 10.49624 | 5.51236 | 5.25194 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 2.0601 | 2 | 3909 | 0.1276 |
| Brown-Forsythe | 3.7195 | 2 | 3909 | 0.0243 |
| Levene | 3.5589 | 2 | 3909 | 0.0286 |
| Bartlett | 19.6651 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 14.1484 | 2 | 31.419 | <.0001 |

**Figure A.2- 166 Statistical Tests for Lateral Error and Vertical Phase of Flight at Look Ahead Time 1800 for Samples at Altitudes Above 18,000 Feet**




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 13 | 1.44341 | 14.4660 | 4.0122 |
| DES | 392 | 1.22113 | 7.8844 | 0.3982 |
| LEV | 3507 | 0.79997 | 11.3369 | 0.1914 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | ASC | DES | LEV |
|---|---|---|---|
| ASC | 0.000000 | 0.222276 | 0.643442 |
| DES | -0.22228 | 0.000000 | 0.421166 |
| LEV | -0.64344 | -0.42117 | 0.000000 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34460

| Abs(Dif)-LSD | ASC | DES | LEV |
|---|---|---|---|
| ASC | -10.1632 | -7.0824 | -6.5563 |
| DES | -7.0824 | -1.8508 | -0.9588 |
| LEV | -6.5563 | -0.9588 | -0.6188 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 13 | 14.46603 | 11.37245 | 11.36032 |
| DES | 392 | 7.88442 | 5.56505 | 5.56489 |
| LEV | 3507 | 11.33686 | 7.22808 | 7.19496 |

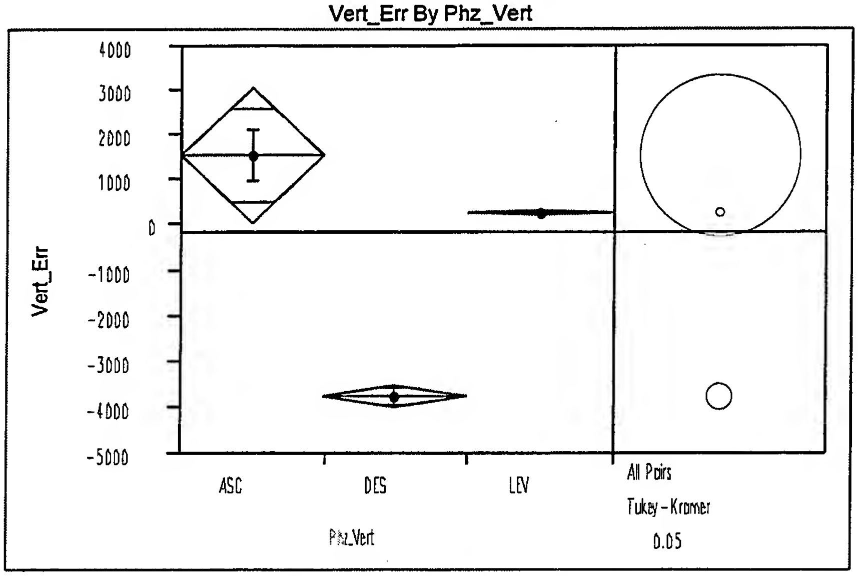
| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 6.6445 | 2 | 3909 | 0.0013 |
| Brown-Forsythe | 8.1257 | 2 | 3909 | 0.0003 |
| Levene | 8.4767 | 2 | 3909 | 0.0002 |
| Bartlett | 38.8478 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 0.4545 | 2 | 31.474 | 0.6388 |

**Figure A.2- 167 Statistical Tests for Longitudinal Error and Vertical Phase of Flight at Look Ahead Time 1800 for Samples at Altitudes Above 18,000 Feet**

Vert_Err By Phz_Vert




Means and Std Deviations

| Level | Number | Mean | Std Dev | Std Err Mean |
|---|---|---|---|---|
| ASC | 13 | 1569.38 | 2217.34 | 614.98 |
| DES | 392 | -3744.79 | 4239.04 | 214.10 |
| LEV | 3507 | 268.79 | 2607.02 | 44.02 |

Means Comparisons

| Dif=Mean[i]-Mean[j] | ASC | LEV | DES |
|---|---|---|---|
| ASC | 0.00 | 1300.60 | 5314.18 |
| LEV | -1300.60 | 0.00 | 4013.58 |
| DES | -5314.18 | -4013.58 | 0.00 |

Alpha= 0.05

Comparisons for all pairs using Tukey-Kramer HSD

q* = 2.34460

| Abs(Dif)-LSD | ASC | LEV | DES |
|---|---|---|---|
| ASC | -2586.15 | -531.48 | 3455.41 |
| LEV | -531.48 | -157.46 | 3662.44 |
| DES | 3455.41 | 3662.44 | -470.96 |

Positive values show pairs of means that are significantly different.

Tests that the Variances are Equal

| Level | Count | Std Dev | MeanAbsDif to Mean | MeanAbsDif to Median |
|---|---|---|---|---|
| ASC | 13 | 2217.340 | 1651.030 | 1617.077 |
| DES | 392 | 4239.042 | 3332.325 | 3316.254 |
| LEV | 3507 | 2607.018 | 1183.840 | 1011.159 |

| Test | F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|---|
| O'Brien[.5] | 21.7994 | 2 | 3909 | <.0001 |
| Brown-Forsythe | 156.9285 | 2 | 3909 | <.0001 |
| Levene | 147.2733 | 2 | 3909 | <.0001 |
| Bartlett | 106.4583 | 2 | ? | <.0001 |

Welch Anova testing Means Equal, allowing Std's Not Equal

| F Ratio | DF Num | DF Den | Prob>F |
|---|---|---|---|
| 167.8343 | 2 | 31.418 | <.0001 |

**Figure A.2- 168 Statistical Tests for Vertical Error and Vertical Phase of Flight at Look Ahead Time 1800 for Samples at Altitudes Above 18,000 Feet**

# Trajectory Prediction Accuracy Report: User Request Evaluation Tool (URET)/ Center-TRACON Automation System (CTAS)

## APPENDIX B: Listing of Standard Deviation Plots

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Mary Lee Cale

May 1999

DOT/FAA/CT-TN99/10

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# Table of Contents for Appendix B

# APPENDIX B

## B.0 Introduction

Appendix B is a supplement to *Trajectory Prediction Accuracy Report: User Request Evaluation Tool (URET)/Center-TRACON Automation System (CTAS), DOT/FAA/CT-TN99/10*. The Appendix B contains a super set list of Microsoft PowerPoint slides from the Enroute Area Work Team (ERAWT) quarterly meeting held April 20-21 at MITRE, where the preliminary analysis of this report was presented.

The PowerPoint slides provide the standard deviation (STD) for horizontal, lateral, longitudinal and vertical error by look ahead time for the flight categories analyzed in the report – flight type, horizontal and vertical error. Additional slides from the presentation that duplicate information provided earlier in this report have been excluded.

The remaining portions of this introduction to Appendix B summarize the slide sequence and provide a brief description of the slides and method used to calculate the STD statistics.

### *B.0.1. Appendix Layout*

Appendix B presents the standard deviations as a function of look ahead time and in order of the particular trajectory modeler and three factor categories. These categories are listed in the PowerPoint slide headings, including flight type, horizontal and vertical phase of flight. Table B.0-1 summaries the slide sequence. Appendix Section B.1 contains slides pertaining to the URET trajectory modeler and Appendix B.2 provides slides for the CTAS modeler.

**Table B.0- 1: Standard Deviation Slides by Trajectory Modeler**

| | | | |
|---|---|---|---|
| **B.1** | **URET** | **B.2** | **CTAS** |
| *B.1.1* | *Flight Type* | *B.2.1* | *Flight Type* |
| | *Flight Type – All Altitudes*<br>Horizontal Error<br>Lateral Error<br>Longitudinal Error<br>Vertical Error | | *Flight Type – All Altitudes*<br>Horizontal Error<br>Lateral Error<br>Longitudinal Error<br>Vertical Error |
| | *Flight Type – Above 18,000 Feet*<br>Horizontal Error<br>Lateral Error<br>Longitudinal Error<br>Vertical Error | | *Flight Type – Above 18,000 Feet*<br>Horizontal Error<br>Lateral Error<br>Longitudinal Error<br>Vertical Error |
| *B.1.2* | *Horizontal Phase of Flight* | *B.2.2* | *Horizontal Phase of Flight* |
| | Same sequence | | Same sequence |
| *B.1.3* | *Vertical Phase of Flight* | *B.2.3* | *Vertical Phase of Flight* |
| | Same sequence | | Same sequence |

### B.0.2. Description of PowerPoint Slides for STD

Figure B.0-1 is an example a PowerPoint slide for the standard deviation (STD) of the horizontal error for the flight type factor. The category along the horizontal axis for all STD slides is look ahead time. Look ahead time is shown in 600 second increments from 0 to 1800 seconds. The units along the vertical axis (not shown) are nautical miles for slides with horizontal, lateral, and longitudinal error and feet for slides with vertical error.

Comparable to the charts plotted for mean error in the body of the report in Sections 3.3 and 4.3, the following factors were plotted to evaluate standard deviation: overflights, arrivals, departures, and internal flights (i.e. OVR, ARR, DEP, and INR, respectively) for the flight type category, turn and straight for horizontal phase of flight (i.e. TRN and STR, respectively), and ascent, descent, and level flight for the vertical phase of flight (i.e. ASC, DES, and LEV, respectively).

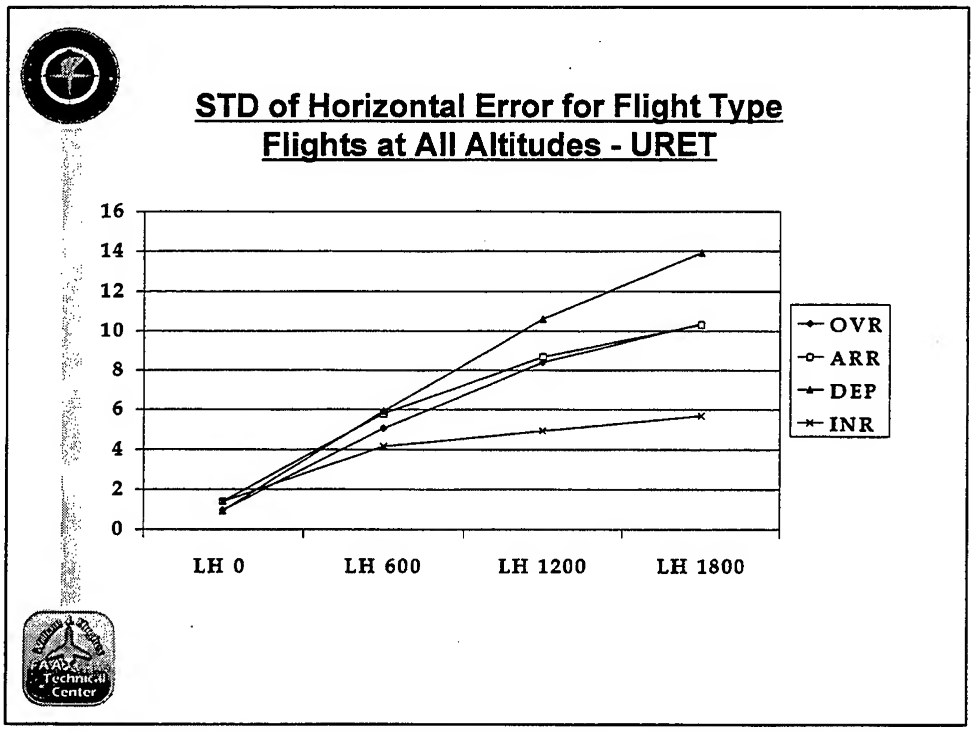



**Figure B:0-1 Example of PowerPoint Slide for Standard Deviation**

### *B.0.3. Definition of Standard Deviation*

Standard deviation (STD) measures the spread of a distribution of observations about the mean. The sample standard deviation is calculated as the square root of the variance,

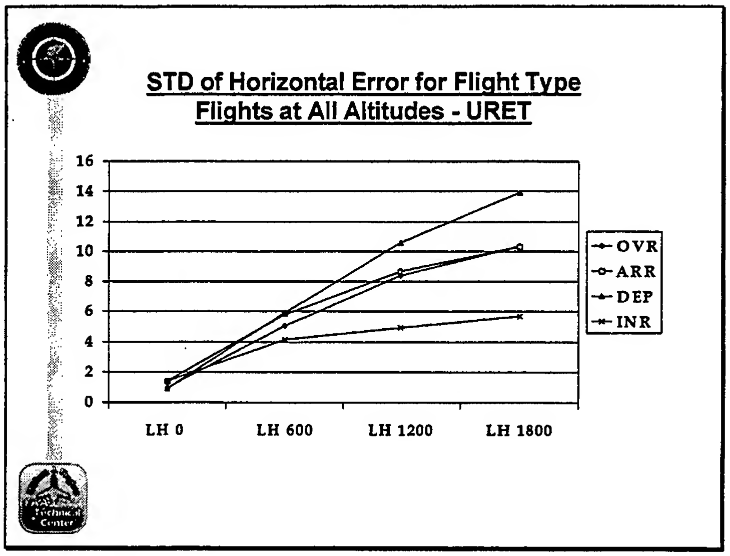
$$s^2 = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n-1}}$$ **Equation B.0-1**

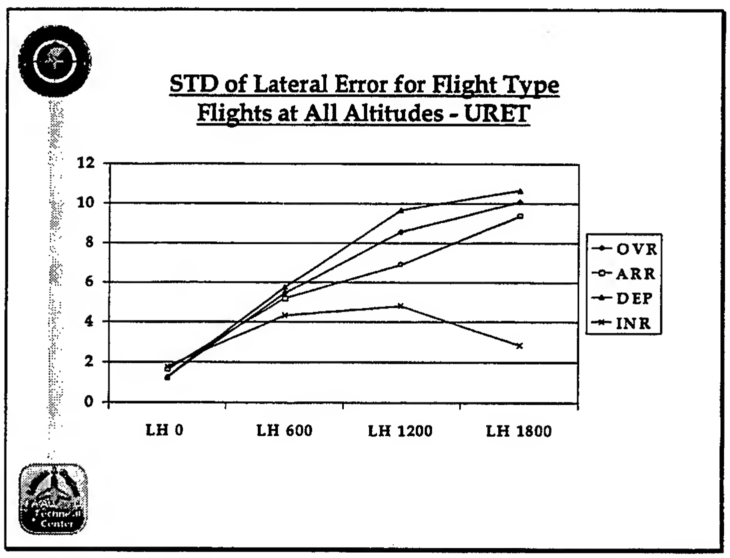
where

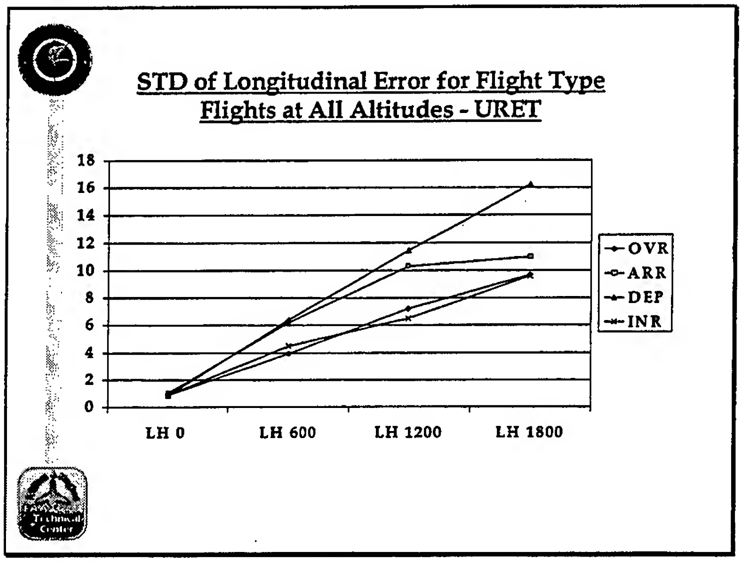
$x_i$ is a data point
$\bar{x}$ is the sample mean
$n$ is the sample size

# B.1 URET PowerPoint Slides for Standard Deviation

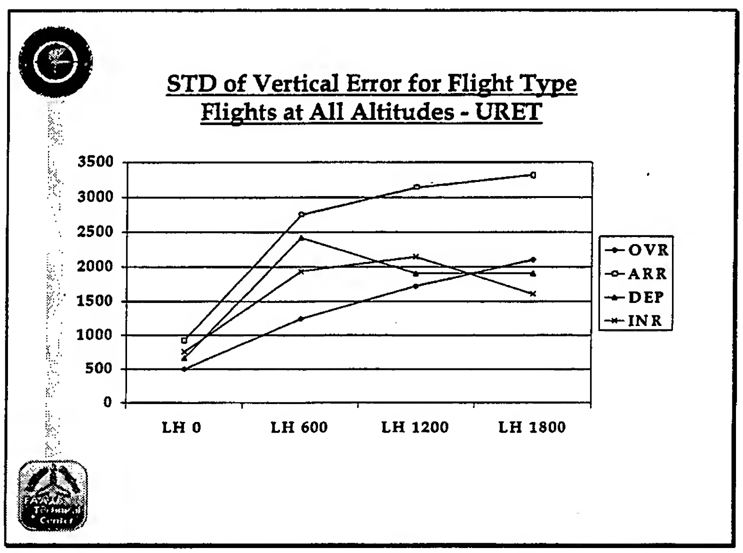
## *B.1.1 Flight Type*



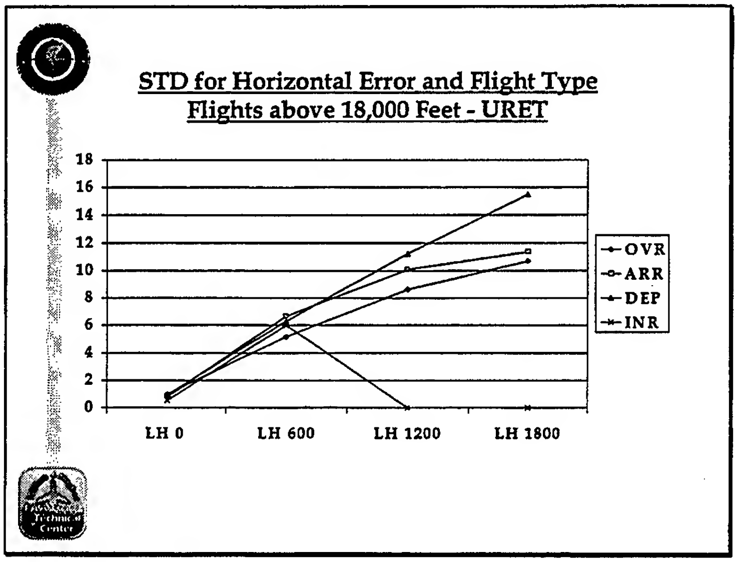



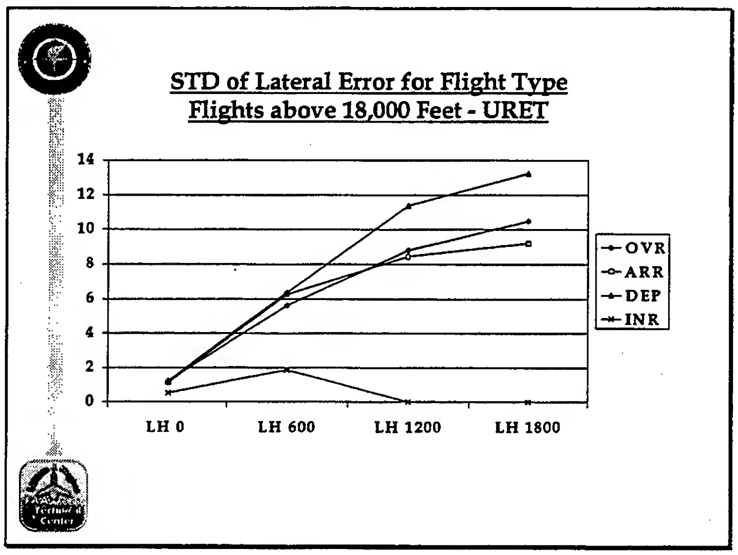


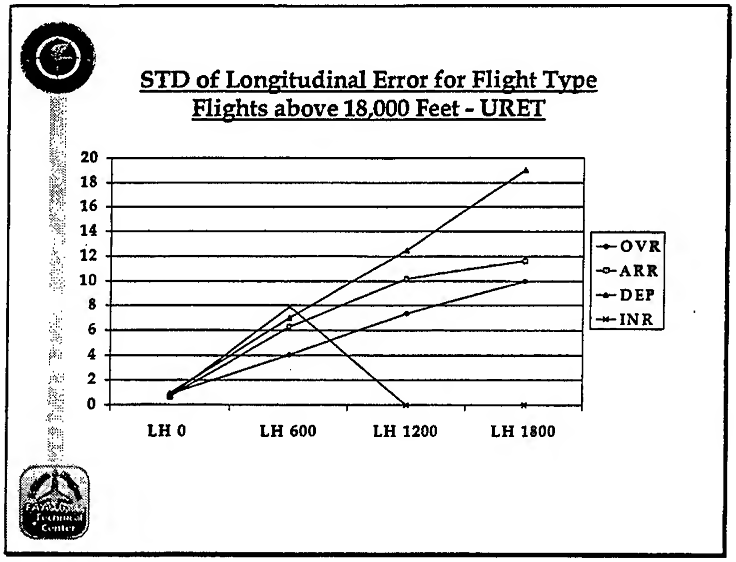
STD of Longitudinal Error for Flight Type Flights at All Altitudes - URET
18
16
14
12
10
8
6
4
2
0
LH 0
LH 600
LH 1200
LH 1800
OVR
ARR
DEP
INR

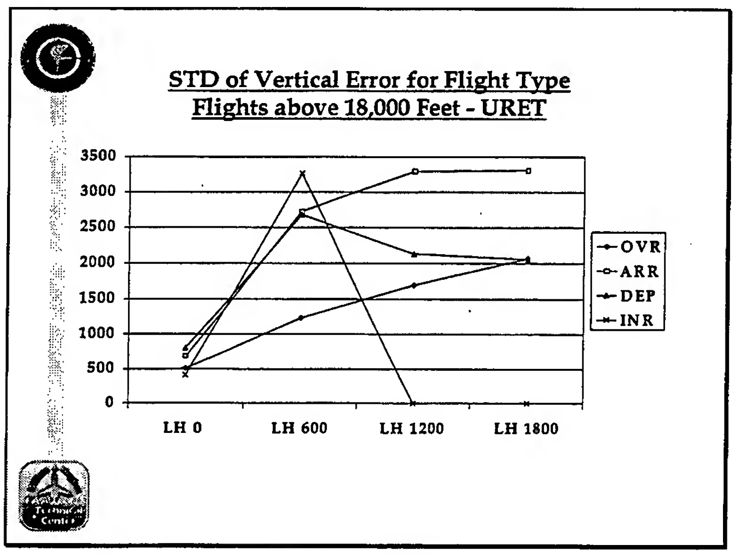



STD of Vertical Error for Flight Type Flights at All Altitudes - URET
3500
3000
2500
2000
1500
1000
500
0
LH 0
LH 600
LH 1200
LH 1800
OVR
ARR
DEP
INR

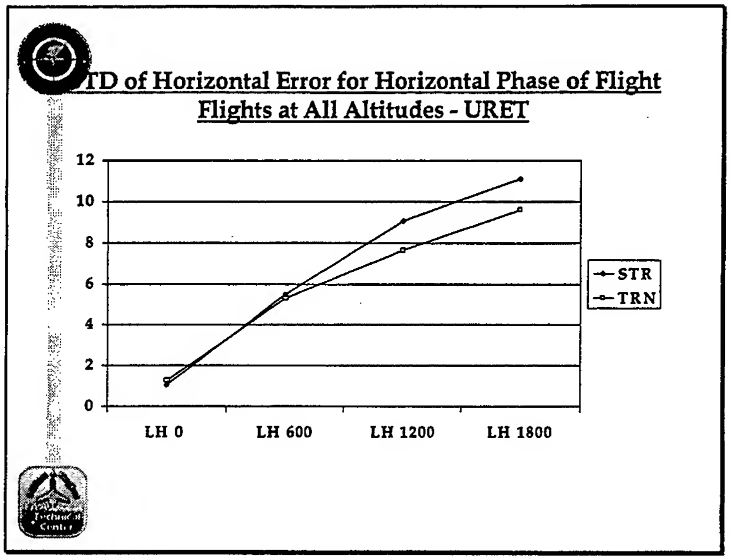

STD for Horizontal Error and Flight Type
Flights above 18,000 Feet - URET
18
16
14
12
10
8
6
4
2
0
LH 0
LH 600
LH 1200
LH 1800
OVR
ARR
DEP
INR

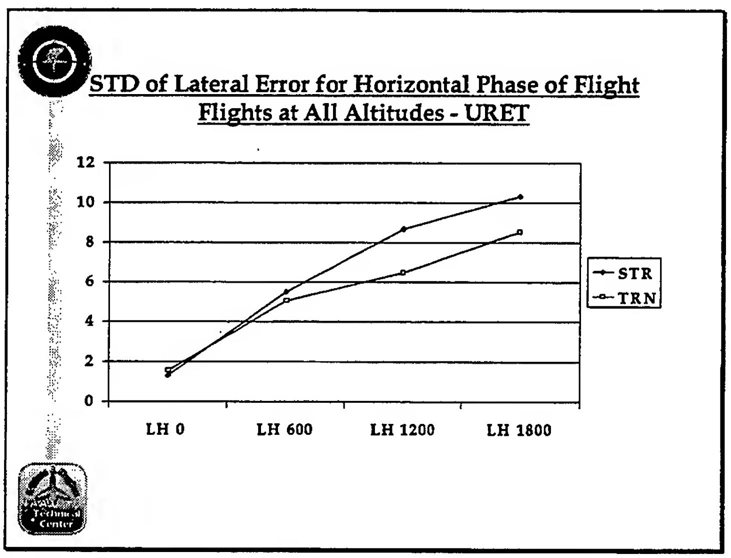

STD of Lateral Error for Flight Type
Flights above 18,000 Feet - URET
14
12
10
8
6
4
2
0
LH 0
LH 600
LH 1200
LH 1800
OVR
ARR
DEP
INR


STD of Longitudinal Error for Flight Type
Flights above 18,000 Feet - URET
20
18
16
14
12
10
8
6
4
2
0
LH 0
LH 600
LH 1200
LH 1800
OVR
ARR
DEP
INR

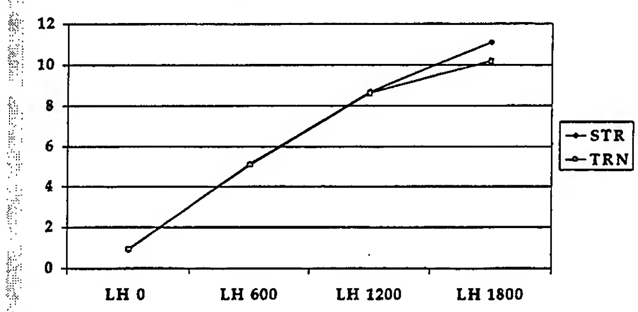

STD of Vertical Error for Flight Type
Flights above 18,000 Feet - URET
3500
3000
2500
2000
1500
1000
500
0
LH 0
LH 600
LH 1200
LH 1800
OVR
ARR
DEP
INR

### *B.1.2 Horizontal Phase of Flight*

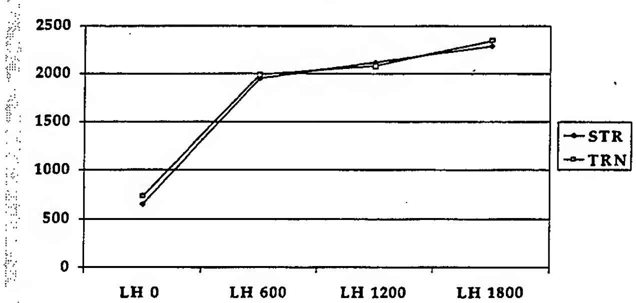


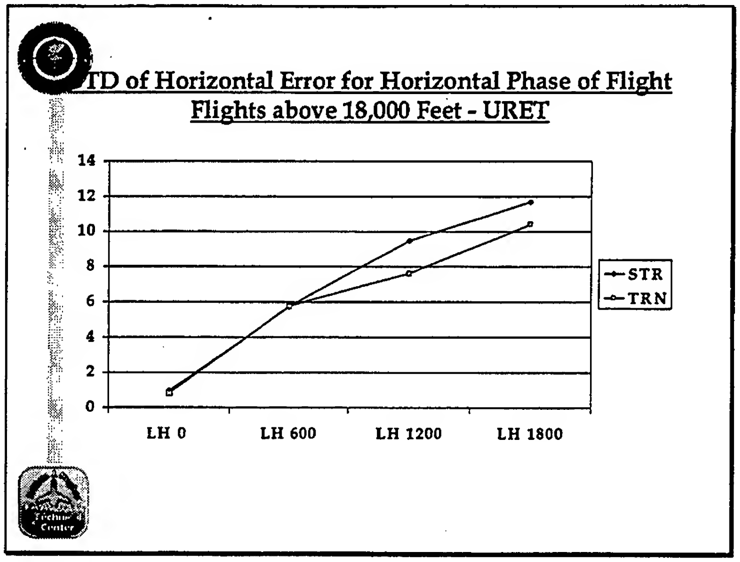



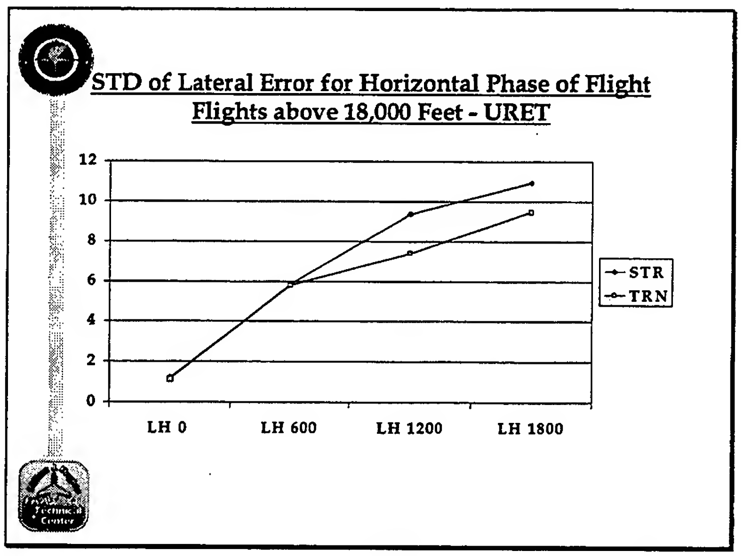
**D of Longitudinal Error for Horizontal Phase of Flight**
**Flights at All Altitudes - URET**

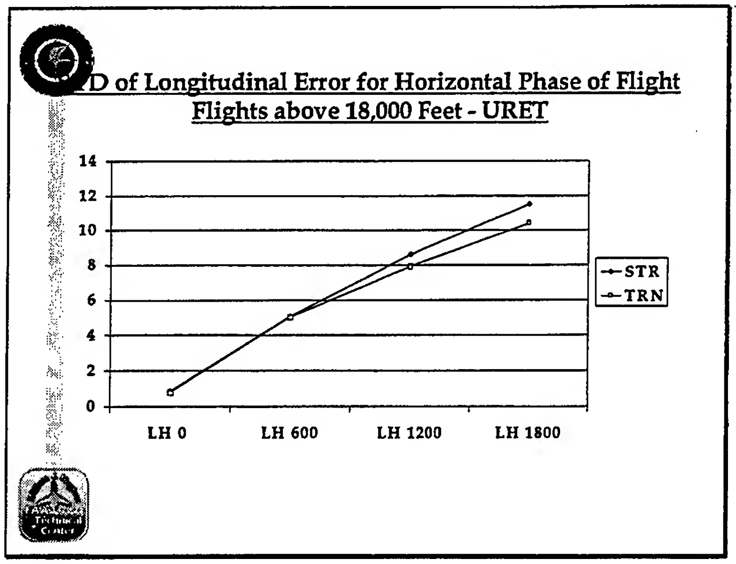


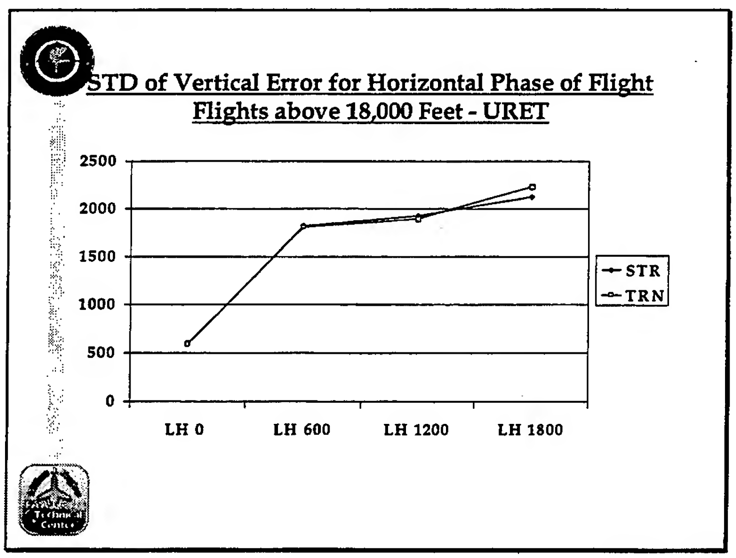

**STD of Vertical Error for Horizontal Phase of Flight**
**Flights at All Altitudes - URET**



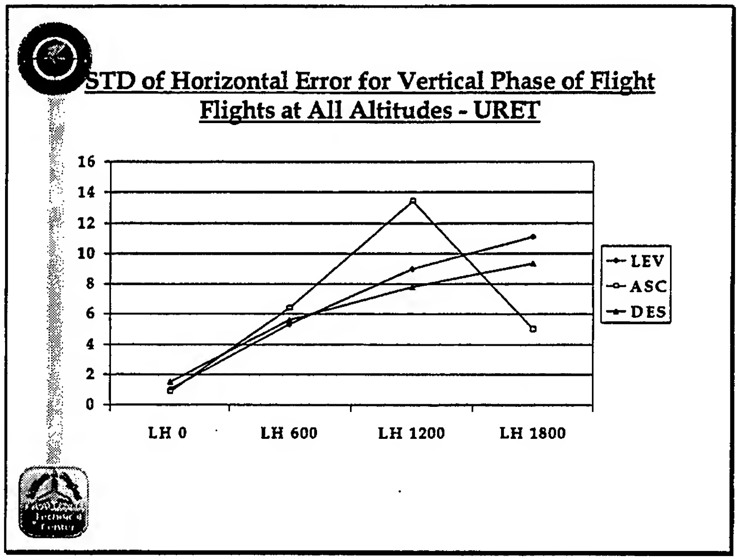

TD of Horizontal Error for Horizontal Phase of Flight
Flights above 18,000 Feet - URET
14
12
10
8
6
4
2
0
LH 0
LH 600
LH 1200
LH 1800
STR
TRN
Technical
Center

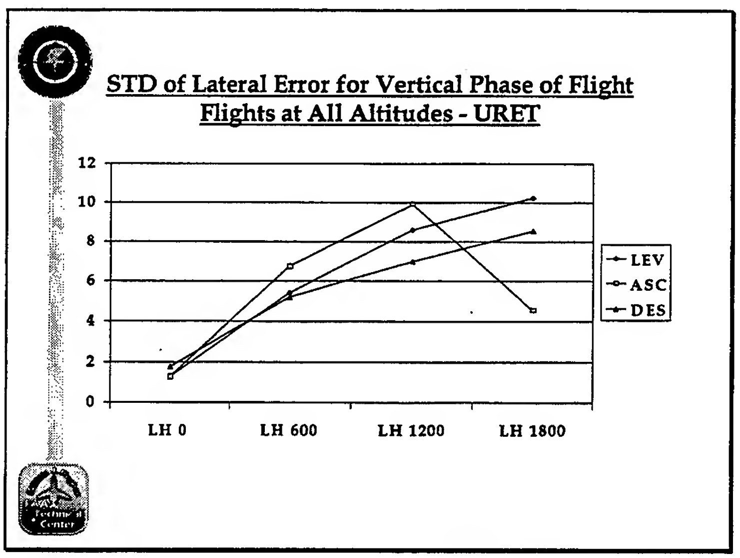

STD of Lateral Error for Horizontal Phase of Flight
Flights above 18,000 Feet - URET
12
10
8
6
4
2
0
LH 0
LH 600
LH 1200
LH 1800
STR
TRN
Technical
Center

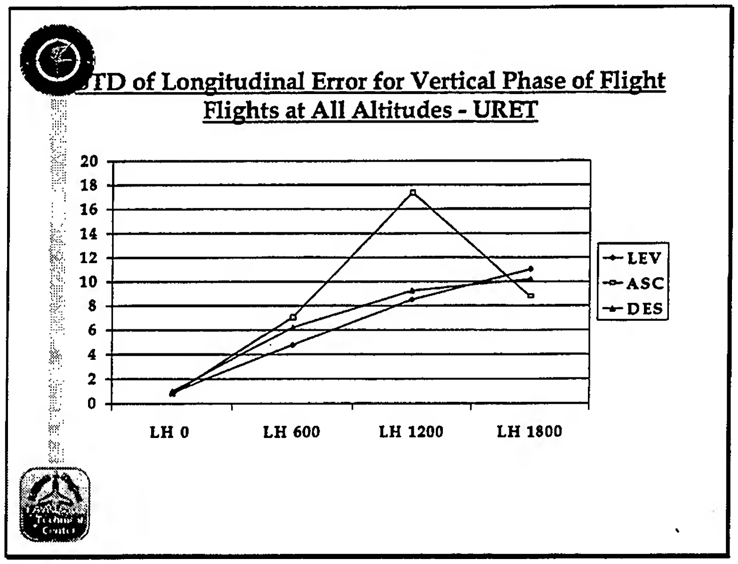

D of Longitudinal Error for Horizontal Phase of Flight
Flights above 18,000 Feet - URET
14
12
10
8
6
4
2
0
LH 0
LH 600
LH 1200
LH 1800
STR
TRN

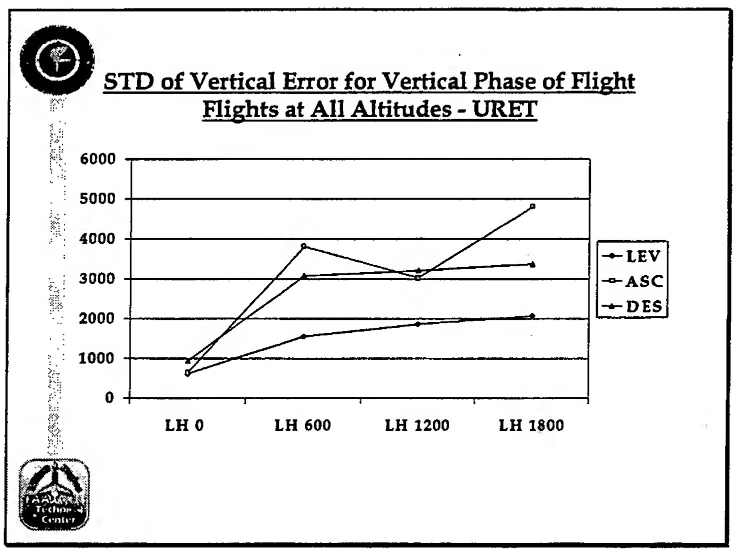

STD of Vertical Error for Horizontal Phase of Flight
Flights above 18,000 Feet - URET
2500
2000
1500
1000
500
0
LH 0
LH 600
LH 1200
LH 1800
STR
TRN

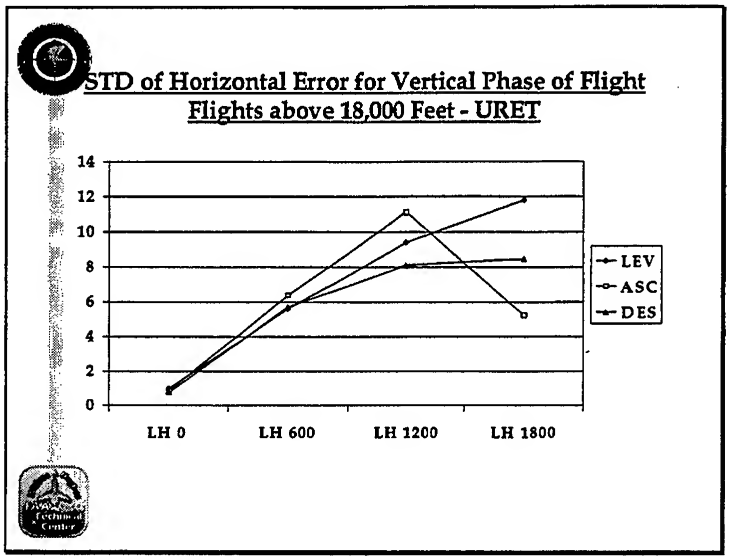
## *B.1.3 Vertical Phase of Flight*

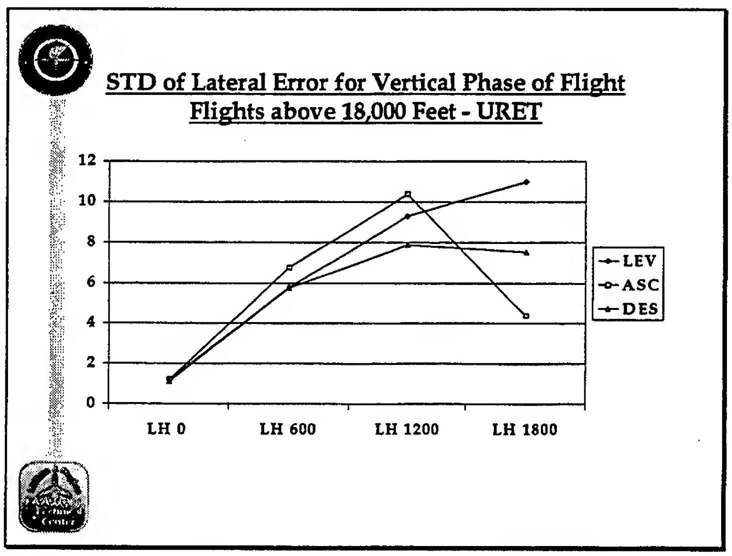


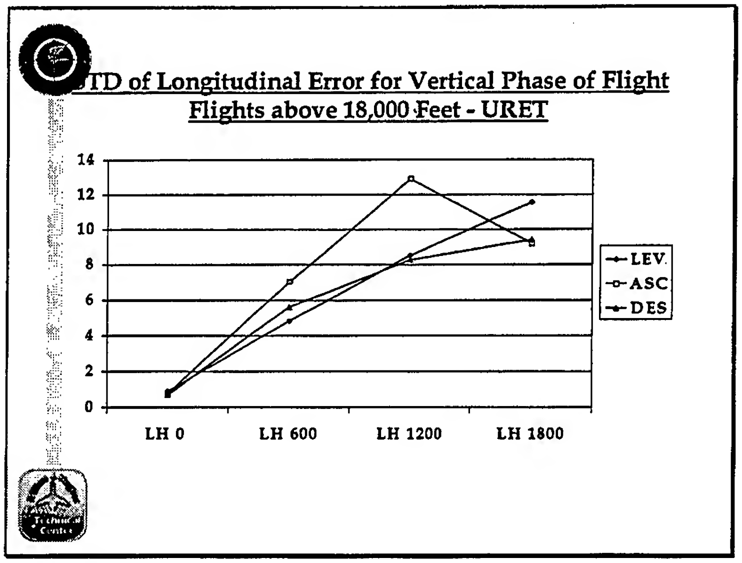



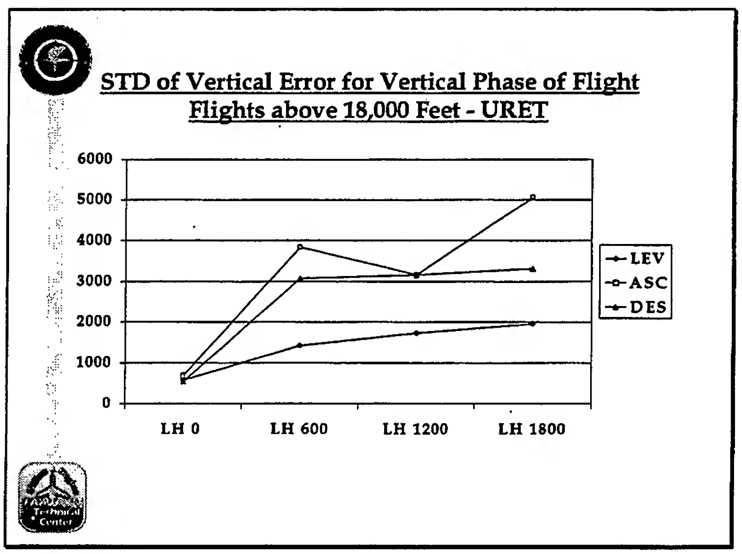

STD of Longitudinal Error for Vertical Phase of Flight
Flights at All Altitudes - URET
20
18
16
14
12
10
8
6
4
2
0
LH 0
LH 600
LH 1200
LH 1800
LEV
ASC
DES


STD of Vertical Error for Vertical Phase of Flight
Flights at All Altitudes - URET
6000
5000
4000
3000
2000
1000
0
LH 0
LH 600
LH 1200
LH 1800
LEV
ASC
DES


STD of Horizontal Error for Vertical Phase of Flight
Flights above 18,000 Feet - URET
14
12
10
8
6
4
2
0
LH 0
LH 600
LH 1200
LH 1800
LEV
ASC
DES

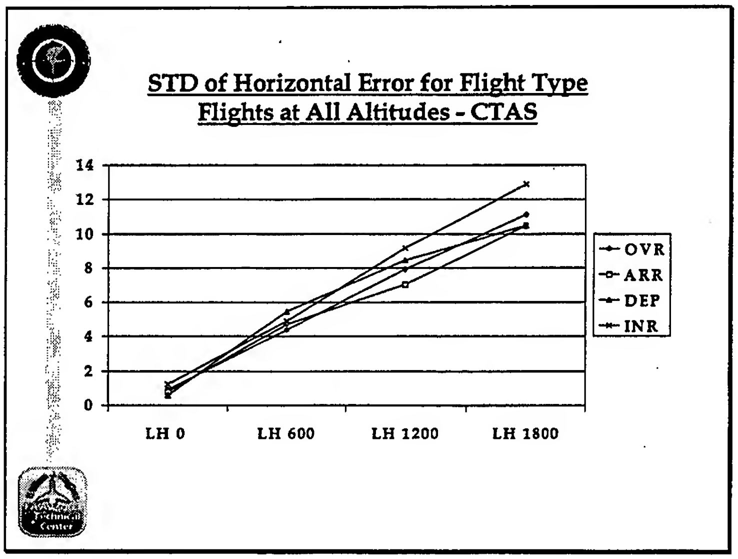

STD of Lateral Error for Vertical Phase of Flight
Flights above 18,000 Feet - URET
12
10
8
6
4
2
0
LH 0
LH 600
LH 1200
LH 1800
LEV
ASC
DES

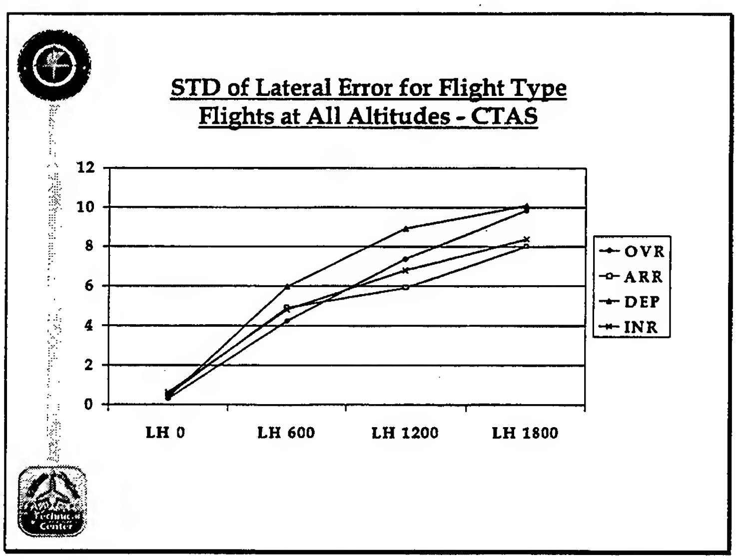

STD of Longitudinal Error for Vertical Phase of Flight
Flights above 18,000 Feet - URET
14
12
10
8
6
4
2
0
LH 0
LH 600
LH 1200
LH 1800
LEV
ASC
DES
Technical Center

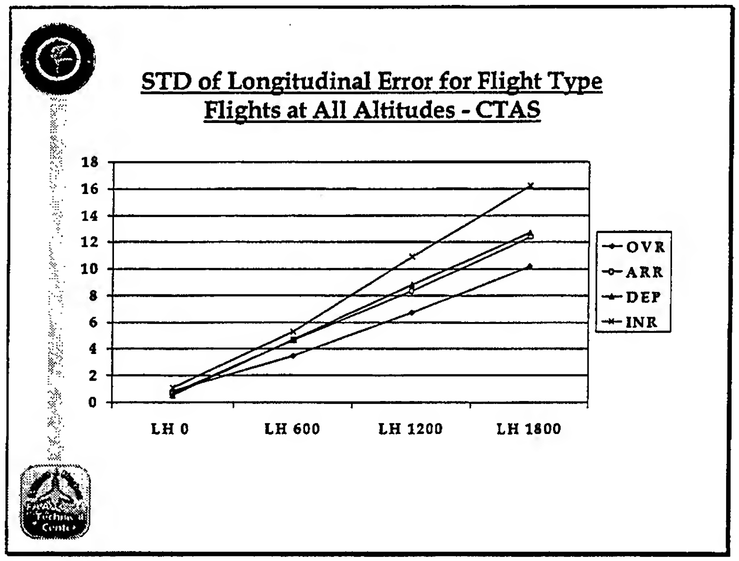

STD of Vertical Error for Vertical Phase of Flight
Flights above 18,000 Feet - URET
6000
5000
4000
3000
2000
1000
0
LH 0
LH 600
LH 1200
LH 1800
LEV
ASC
DES
Technical Center

## B.2 CTAS PowerPoint Slides for Standard Deviation

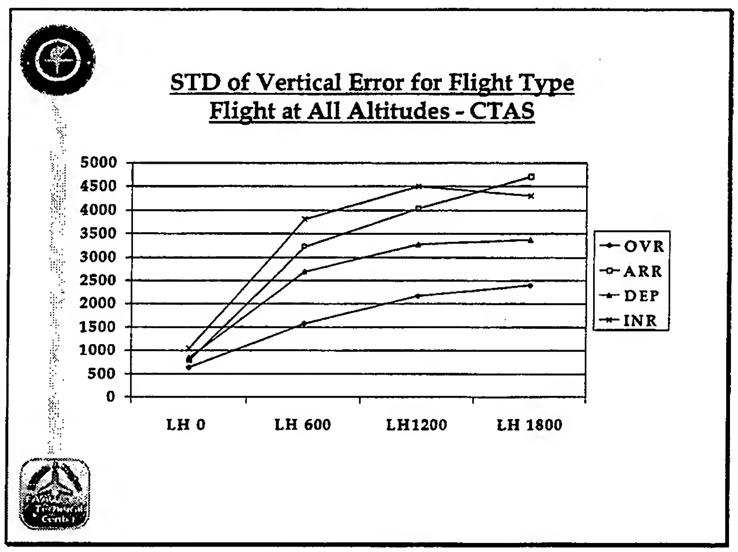
### *B.2.1. Flight Type*



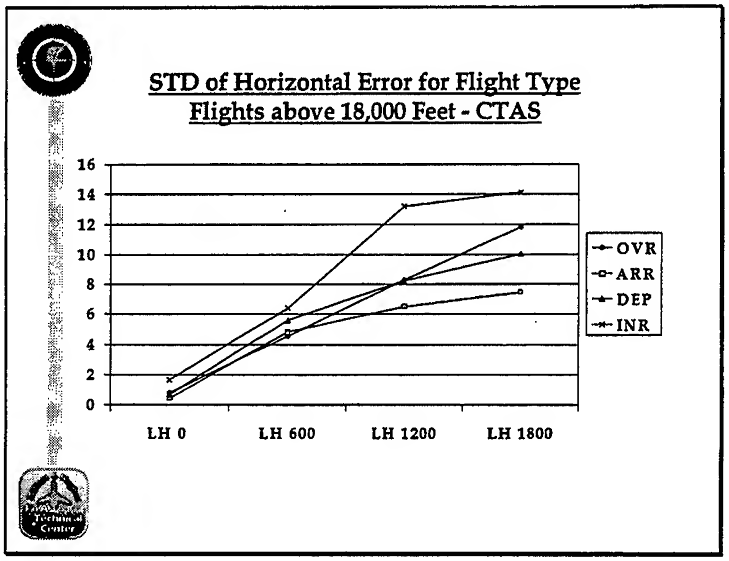



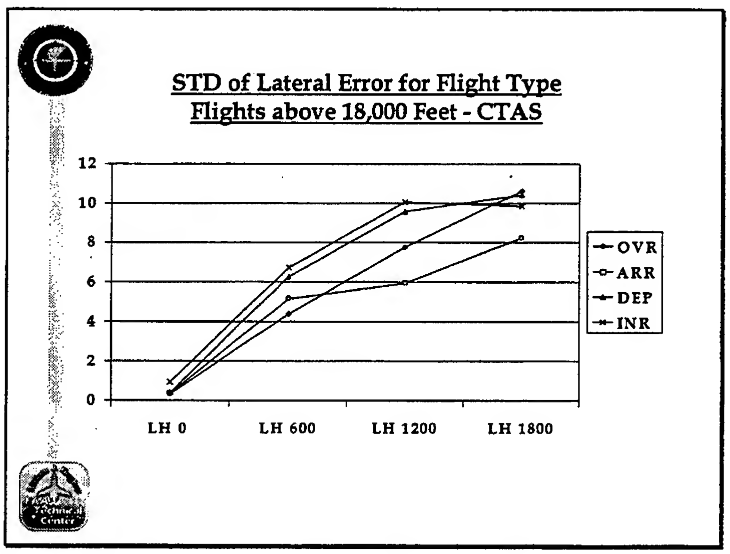


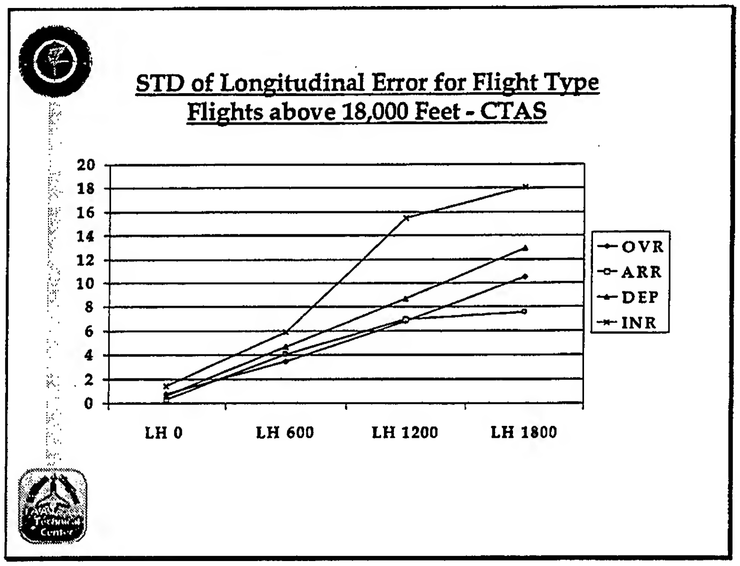
STD of Longitudinal Error for Flight Type Flights at All Altitudes - CTAS
18
16
14
12
10
8
6
4
2
0
LH 0
LH 600
LH 1200
LH 1800
OVR
ARR
DEP
INR

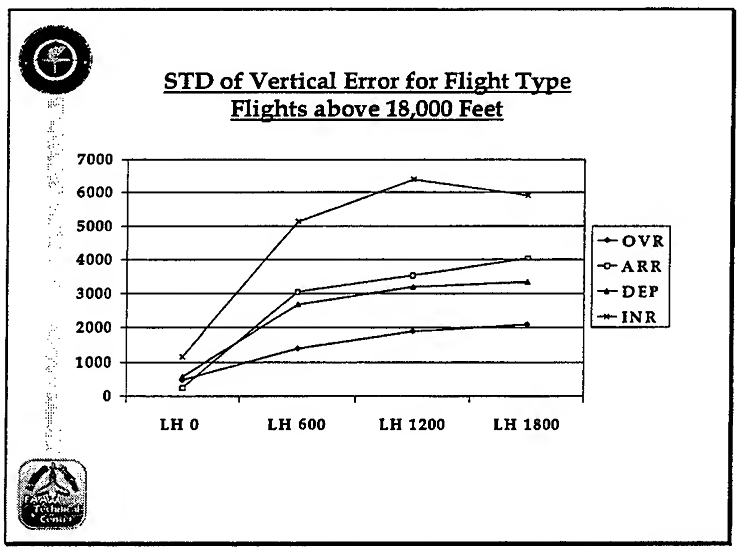
STD of Vertical Error for Flight Type Flight at All Altitudes - CTAS
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
LH 0
LH 600
LH1200
LH 1800
OVR
ARR
DEP
INR


STD of Horizontal Error for Flight Type
Flights above 18,000 Feet - CTAS
16
14
12
10
8
6
4
2
0
LH 0
LH 600
LH 1200
LH 1800
OVR
ARR
DEP
INR


STD of Lateral Error for Flight Type
Flights above 18,000 Feet - CTAS
12
10
8
6
4
2
0
LH 0
LH 600
LH 1200
LH 1800
OVR
ARR
DEP
INR

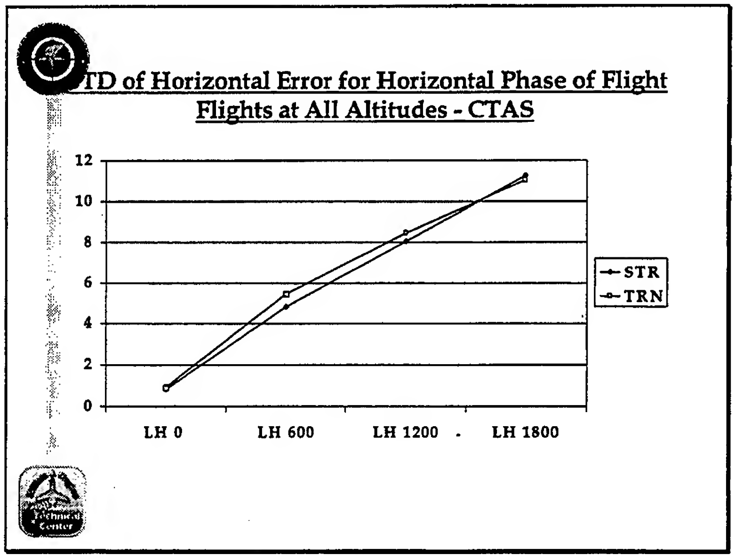


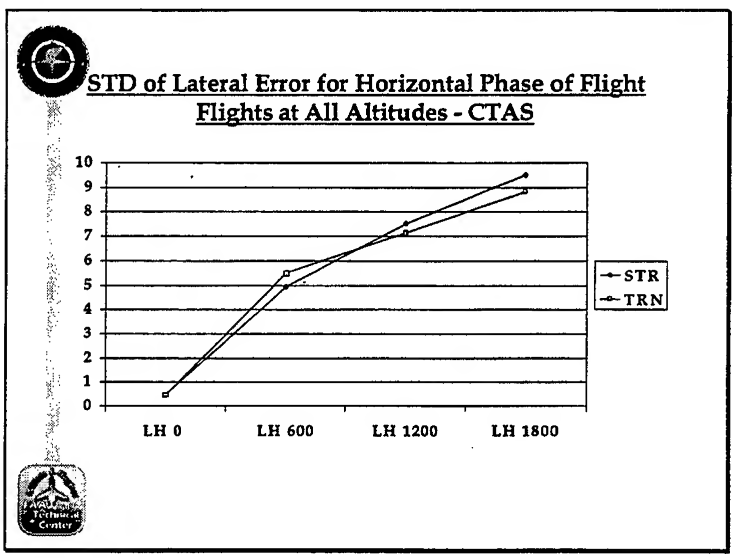
STD of Longitudinal Error for Flight Type
Flights above 18,000 Feet - CTAS
20
18
16
14
12
10
8
6
4
2
0
LH 0
LH 600
LH 1200
LH 1800
OVR
ARR
DEP
INR

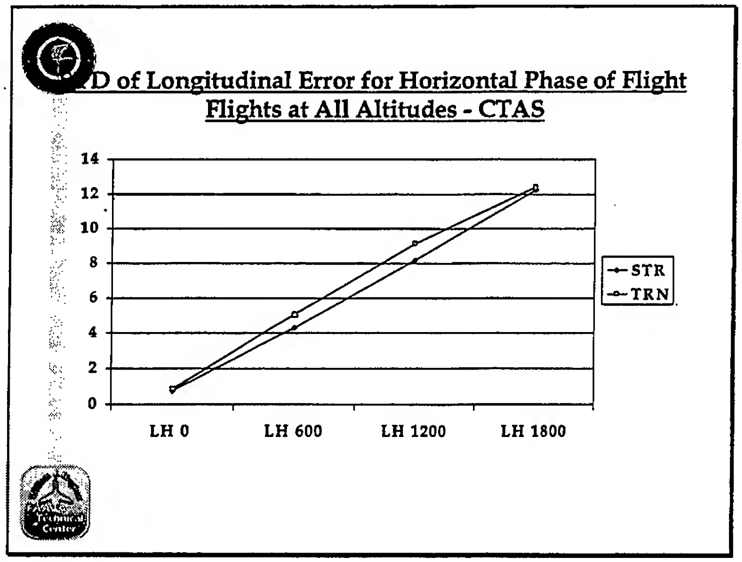



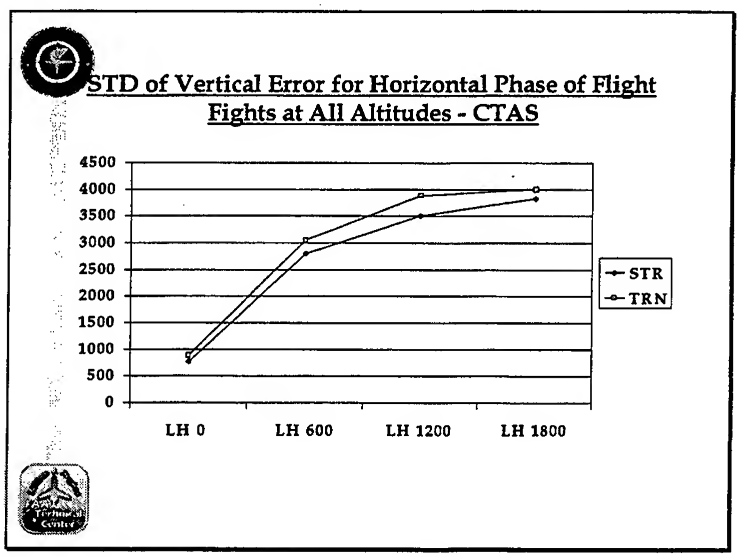
STD of Vertical Error for Flight Type
Flights above 18,000 Feet
7000
6000
5000
4000
3000
2000
1000
0
LH 0
LH 600
LH 1200
LH 1800
OVR
ARR
DEP
INR

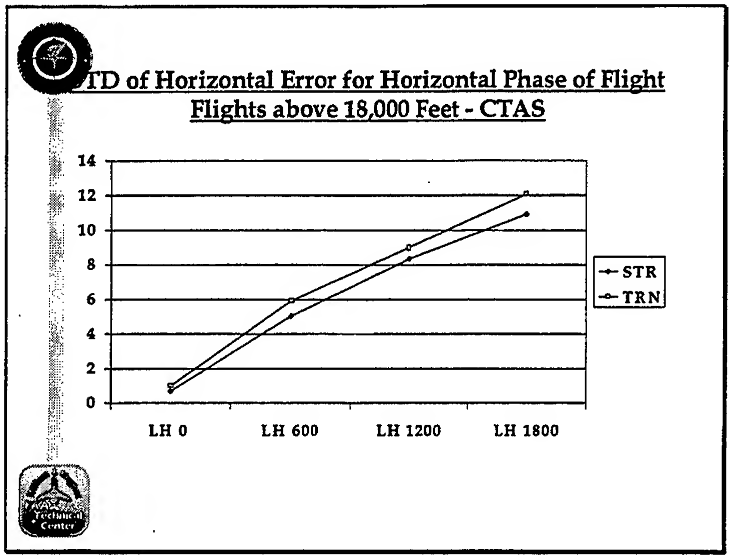
## *B.2.2. Horizontal Phase of Flight*

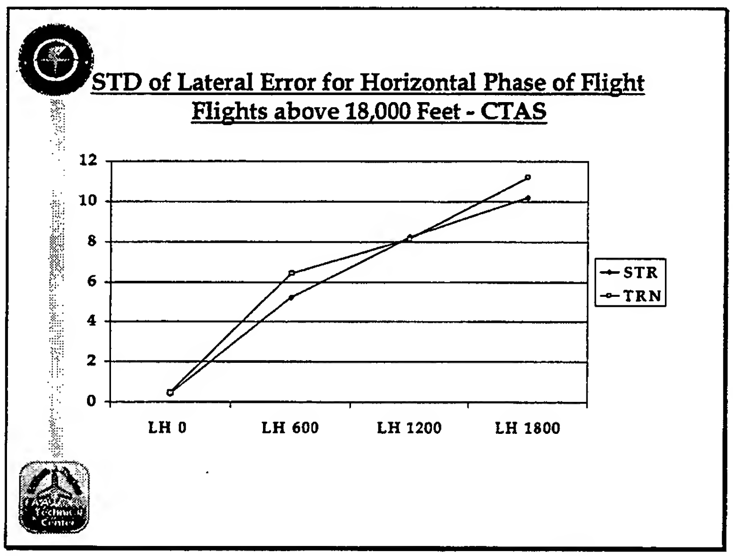


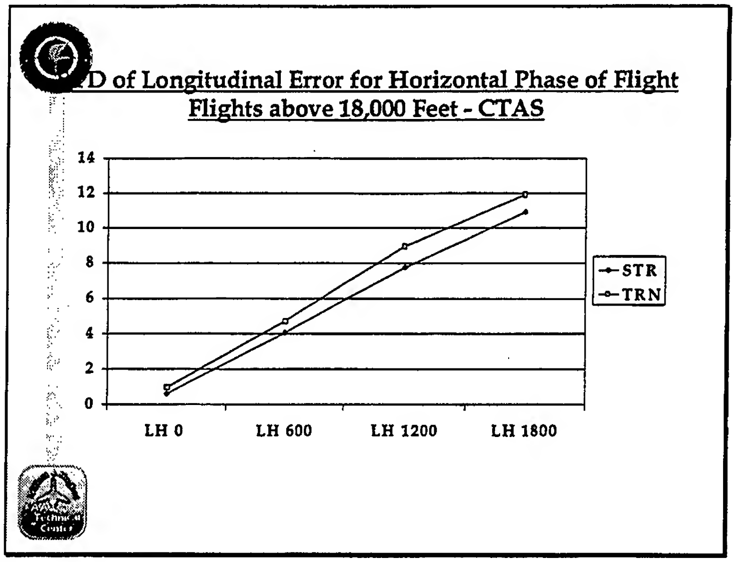




STD of Longitudinal Error for Horizontal Phase of Flight
Flights at All Altitudes - CTAS
14
12
10
8
6
4
2
0
LH 0
LH 600
LH 1200
LH 1800
STR
TRN
Technical Center

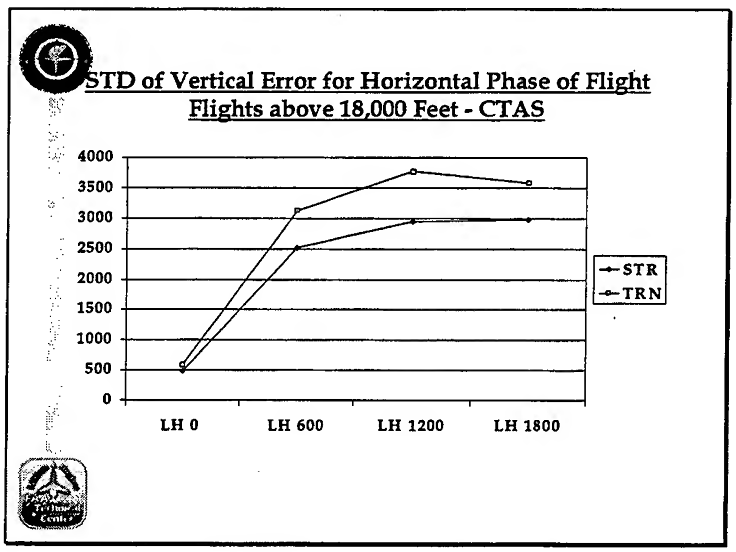

STD of Vertical Error for Horizontal Phase of Flight
Fights at All Altitudes - CTAS
4500
4000
3500
3000
2500
2000
1500
1000
500
0
LH 0
LH 600
LH 1200
LH 1800
STR
TRN
Technical Center


TD of Horizontal Error for Horizontal Phase of Flight
Flights above 18,000 Feet - CTAS
14
12
10
8
6
4
2
0
LH 0
LH 600
LH 1200
LH 1800
STR
TRN


STD of Lateral Error for Horizontal Phase of Flight
Flights above 18,000 Feet - CTAS
12
10
8
6
4
2
0
LH 0
LH 600
LH 1200
LH 1800
STR
TRN

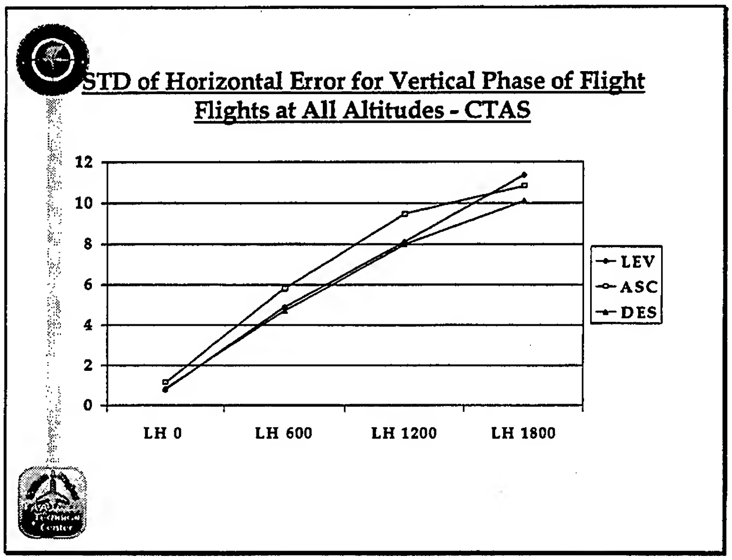


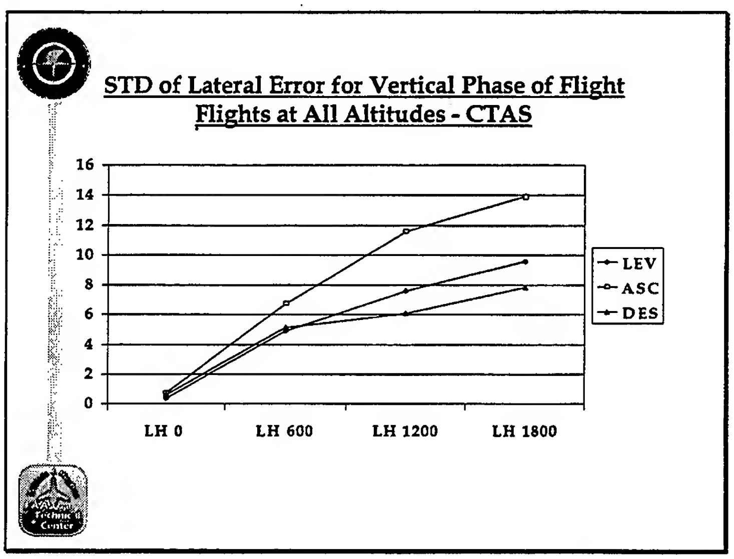
STD of Longitudinal Error for Horizontal Phase of Flight
Flights above 18,000 Feet - CTAS
14
12
10
8
6
4
2
0
LH 0
LH 600
LH 1200
LH 1800
STR
TRN

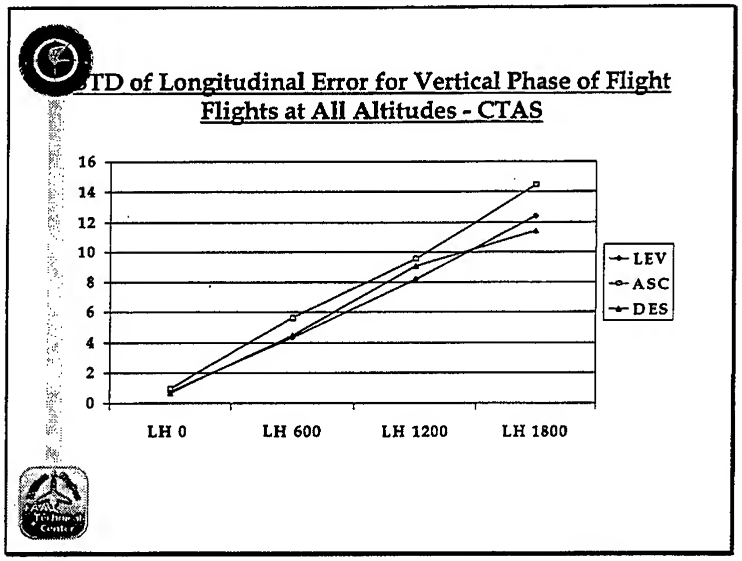



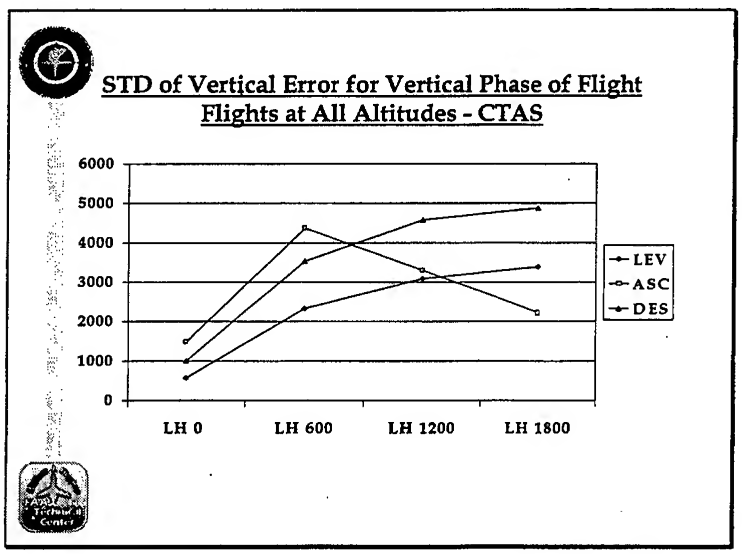
STD of Vertical Error for Horizontal Phase of Flight
Flights above 18,000 Feet - CTAS
4000
3500
3000
2500
2000
1500
1000
500
0
LH 0
LH 600
LH 1200
LH 1800
STR
TRN

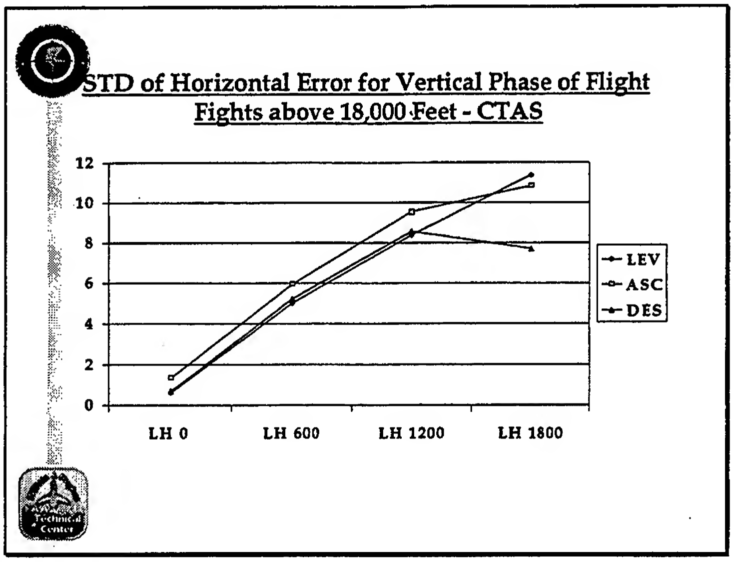
### *B.2.3. Vertical Phase of Flight*

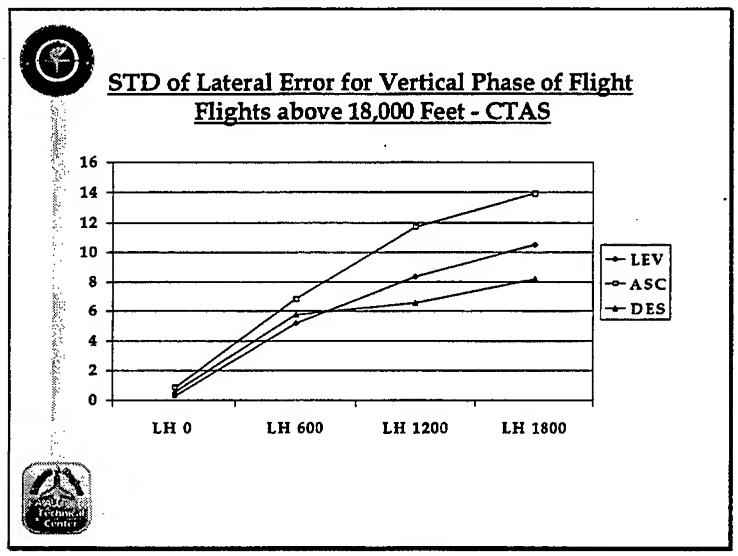


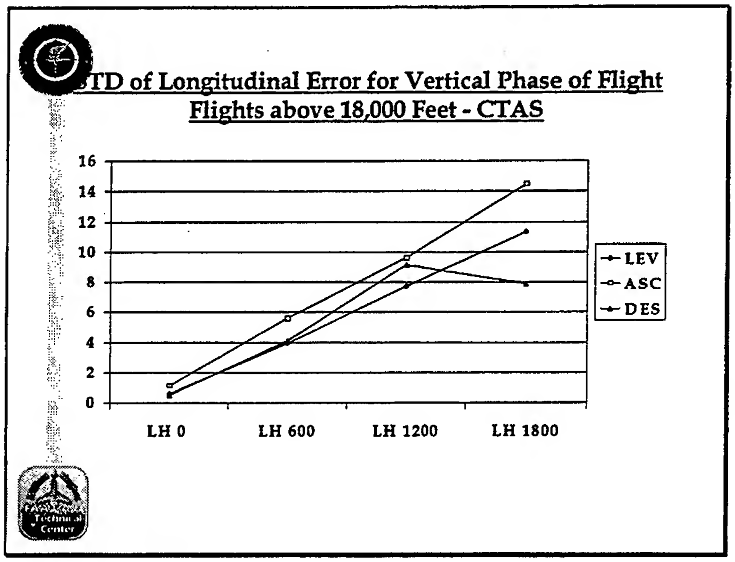



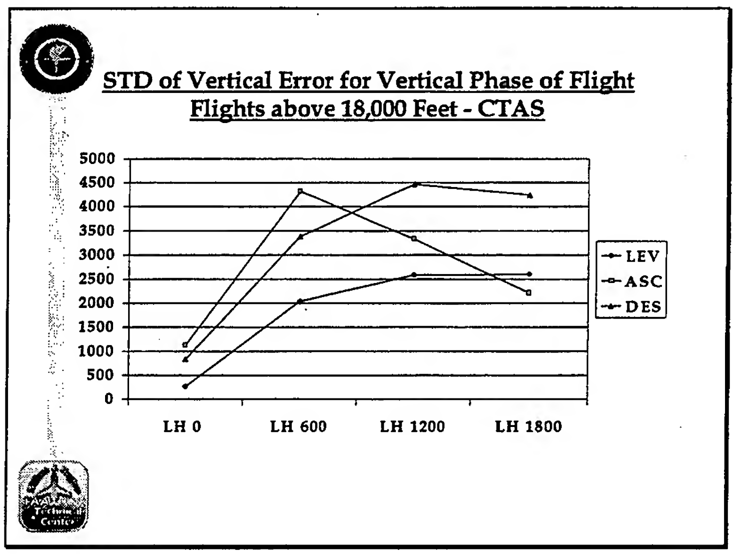

STD of Longitudinal Error for Vertical Phase of Flight
Flights at All Altitudes - CTAS
16
14
12
10
8
6
4
2
0
LH 0
LH 600
LH 1200
LH 1800
LEV
ASC
DES


STD of Vertical Error for Vertical Phase of Flight
Flights at All Altitudes - CTAS
6000
5000
4000
3000
2000
1000
0
LH 0
LH 600
LH 1200
LH 1800
LEV
ASC
DES


STD of Horizontal Error for Vertical Phase of Flight
Fights above 18,000 Feet - CTAS
12
10
8
6
4
2
0
LH 0
LH 600
LH 1200
LH 1800
LEV
ASC
DES


STD of Lateral Error for Vertical Phase of Flight
Flights above 18,000 Feet - CTAS
16
14
12
10
8
6
4
2
0
LH 0
LH 600
LH 1200
LH 1800
LEV
ASC
DES


STD of Longitudinal Error for Vertical Phase of Flight
Flights above 18,000 Feet - CTAS
16
14
12
10
8
6
4
2
0
LH 0
LH 600
LH 1200
LH 1800
LEV
ASC
DES
Technical Center


STD of Vertical Error for Vertical Phase of Flight
Flights above 18,000 Feet - CTAS
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
LH 0
LH 600
LH 1200
LH 1800
LEV
ASC
DES
Technical Center

# Trajectory Prediction Accuracy Report: User Request Evaluation Tool (URET)/ Center-TRACON Automation System (CTAS)

## APPENDIX C: Additional Flight Observations

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Dr. Hollis F. Ryan
Robert D. Oaks
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May 1999

DOT/FAA/CT-TN99/10

U. S. DEPARTMENT OF TRANSPORTATION
Federal Aviation Administration
William J. Hughes Technical Center
Atlantic City International Airport, NJ 08405

# Table of Contents

# APPENDIX C

## C.0 Introduction to Appendix

This Appendix is a supplement to *Trajectory Prediction Accuracy Report: User Request Evaluation Tool (URET)/Center-TRACON Automation System (CTAS)*, FAA ACT-250, 1999. The Appendix contains observations of four anomalous flights (two URET and two CTAS). These flights were selected for detailed study because they exhibited large prediction errors. They were used to verify the software implementation of the methodology. They are included in this Appendix to help the reader understand the methodology. These examples are not necessarily common occurrences and they are not presented as being indicative of any algorithmic problems with either trajectory modeler.

## C.1 URET Observations

### *C.1.1 URET2*

This example, depicting a ZID overflight with adequate track data, provides an example of an aircraft with both large longitudinal errors and large lateral errors. These large prediction errors resulted because the predicted ground speed was in error for a period of time, the aircraft flew by a waypoint, and the trajectory was not updated.

The aircraft, an A320 airbus, overflew the ZID airspace after departing Detroit Metro bound for Cancun. Its flight plan shows that it planned to fly from the Waterville Ohio VORTAC (YWV) to the Rosewood Ohio VORTAC (ROD) to the Nashville VORTAC (BNA). The flight was picked up just north of the ZID airspace at 12:19:10 at Flight Level 277, climbing to Flight Level 350. The track data, which extends from 12:19:10 (44350 seconds) through 13:07:58 (47278 seconds), shows that it flew slightly to the west of that route. This can be seen in Figure C.1-1 which shows the interpolated track XY data and flight plan route. Figure C.1-2 shows the aircraft track altitude vs. time.

#### *C.1.1.1 Track Data*

The HCS track data required only one correction: the first report was deleted because it did not have an altitude value. All the other position reports passed the tests applied by RDTRACKS, with 245 HCS track reports remaining to be processed for this flight.

#### *C.1.1.2 Trajectories*

The entire track time line and the time line for the eight trajectories recovered for this aircraft are presented in Figure C.1-3. The time line for the track is labeled "Track". The time lines for the trajectories are labeled with the trajectory's build time. These eight trajectories consist of four trajectory pairs. The trajectories in each pair are separated by one second in time. Trajectories with the same build time occur occasionally in URET. This happens when output queues build up due to the low priority of URET's data recording process. As a result, trajectories that were actually built at slightly different times may be time stamped with the same build time. Whenever such a trajectory was encountered in this study, one second was added to the build time of that trajectory. The first four trajectories (those labeled 43414 through 44339) were built before the first track point (44350 seconds). The first sample time is 44390. The trajectory used for this sample time was the 44363 trajectory since it was the latest trajectory prior to the sample time. All subsequent sampling and metric calculations use this trajectory also because no more trajectories were generated by URET.

#### *C.1.1.3 Metrics*

As can be seen from Figure C.1-4, initially the track and the trajectory are fairly close. The trajectory routed the flight directly from its current radar position to the next en route waypoint, the Rosewood VORTAC (ROD). However, the aircraft did not proceed to this waypoint but flew by it. The flyby created lateral errors between the trajectory and the track. The aircraft, in bypassing the waypoint, flew directly to the next waypoint, Nashville (BNA). The trajectory predicted the aircraft would fly to this waypoint. The track and the trajectory converged at the Nashville waypoint. Thus, the lateral errors became less and less as the aircraft got closer and closer to the Nashville waypoint. The vertical profile predicted was fairly close to the vertical profile flown. This can be seen in Figure C.1-2.

Figure C.1-5 shows the specific error geometry for a sample time of 44750 and a look ahead time of zero. The aircraft was near the Rosewood VORTAC at this time. The points labeled A, B, and C correspond to the similarly labeled points in Figure 2.5-3 in the report. B is the trajectory point being compared to the track point A. C is the next point on the trajectory, and AD is the

perpendicular to the line BC extended. The lateral error is AD, 3.76 nm, the longitudinal error is BD, 1.54 nm. The sign convention used here is that an aircraft arriving earlier than expected represents a positive longitudinal error, and that a track to the right of the predicted path represents a positive lateral error.

The aircraft flew faster than predicted in the climb to cruising altitude. The trajectory predicted the aircraft would increase its ground speed from 330 knots at FL 280 to 378 knots at FL 350. The airbus actually flew faster: 390 knots at FL 280 and 385 knots at FL 350. A longitudinal error was accumulated during the climb. In level cruise the actual and predicted ground speeds were fairly close. However, the longitudinal error caused by the error in predicted ground speed during the climb persists because the trajectory was not updated.

Table C.1-1 presents the trajectory metrics calculated for this aircraft.

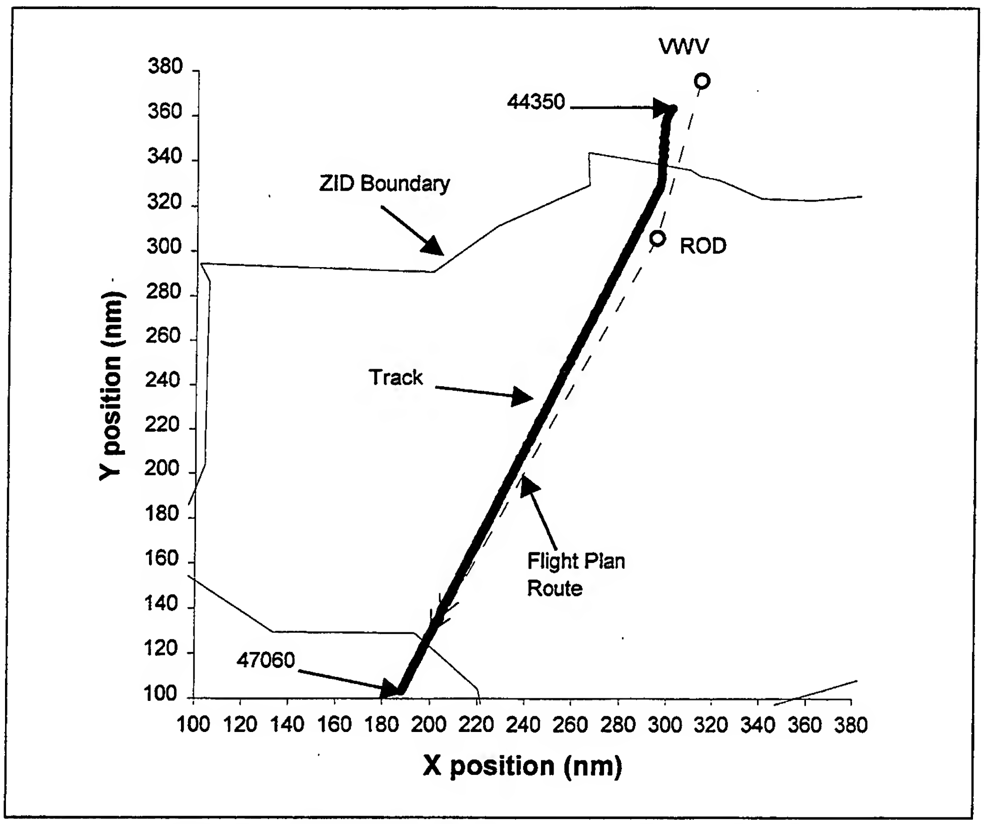


**Figure C.1-1: Interpolated Track Position and Route**

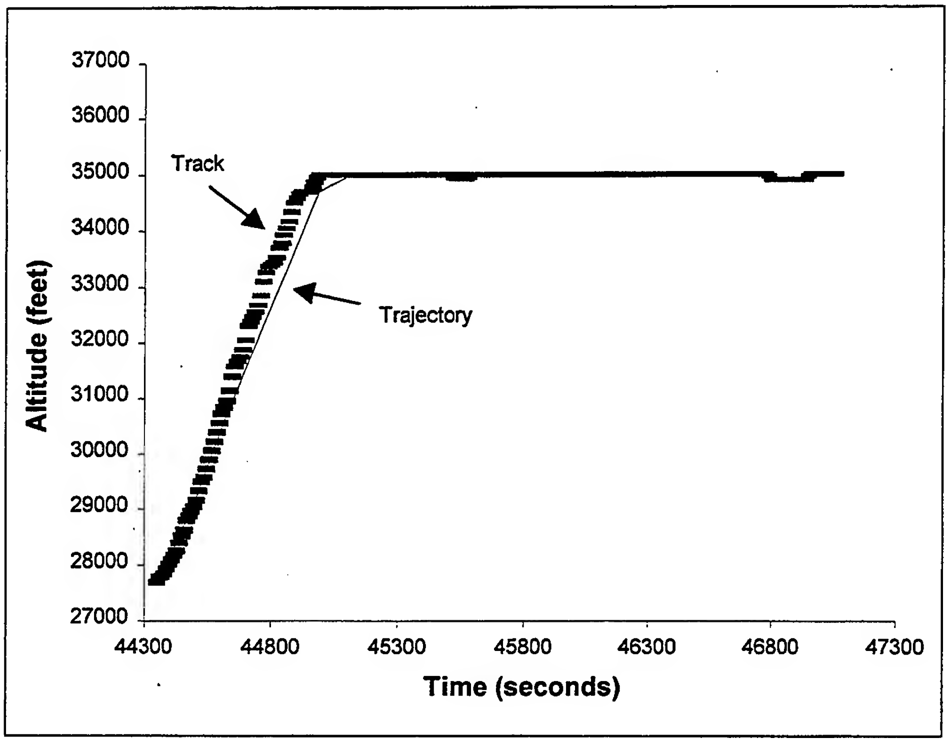


**Figure C.1-2: Interpolated Track Altitude**

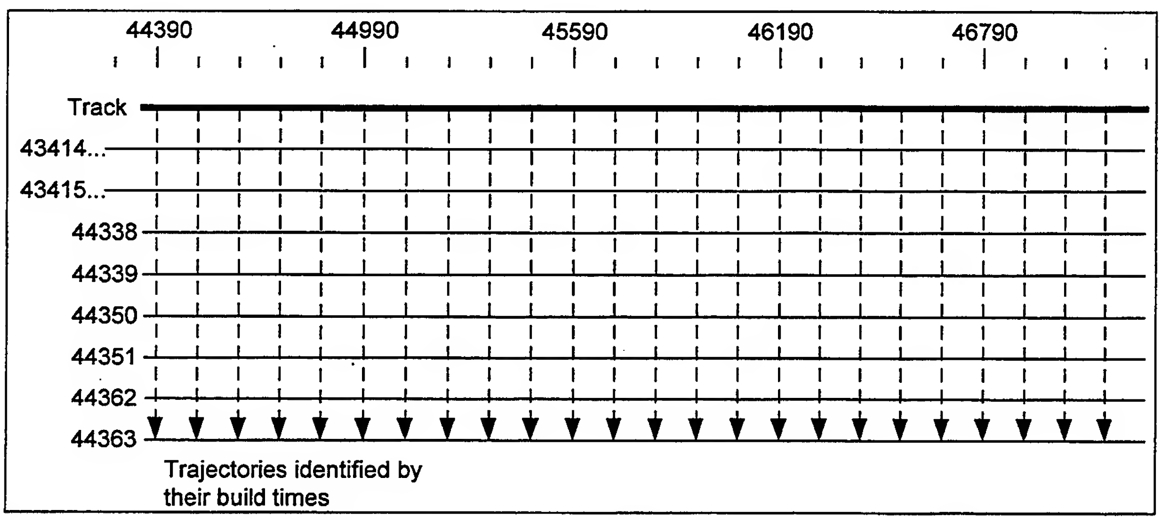


**Figure C.1-3: Sampled Trajectories**

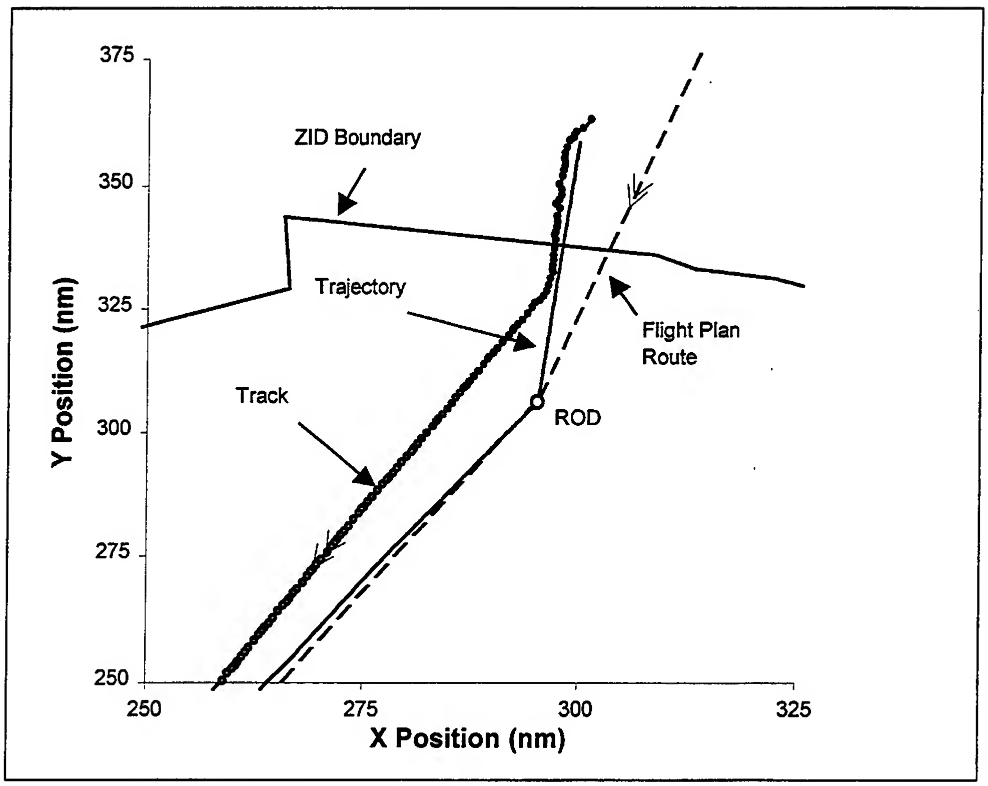


**Figure C.1-4: Track XY and 44363 Trajectory**

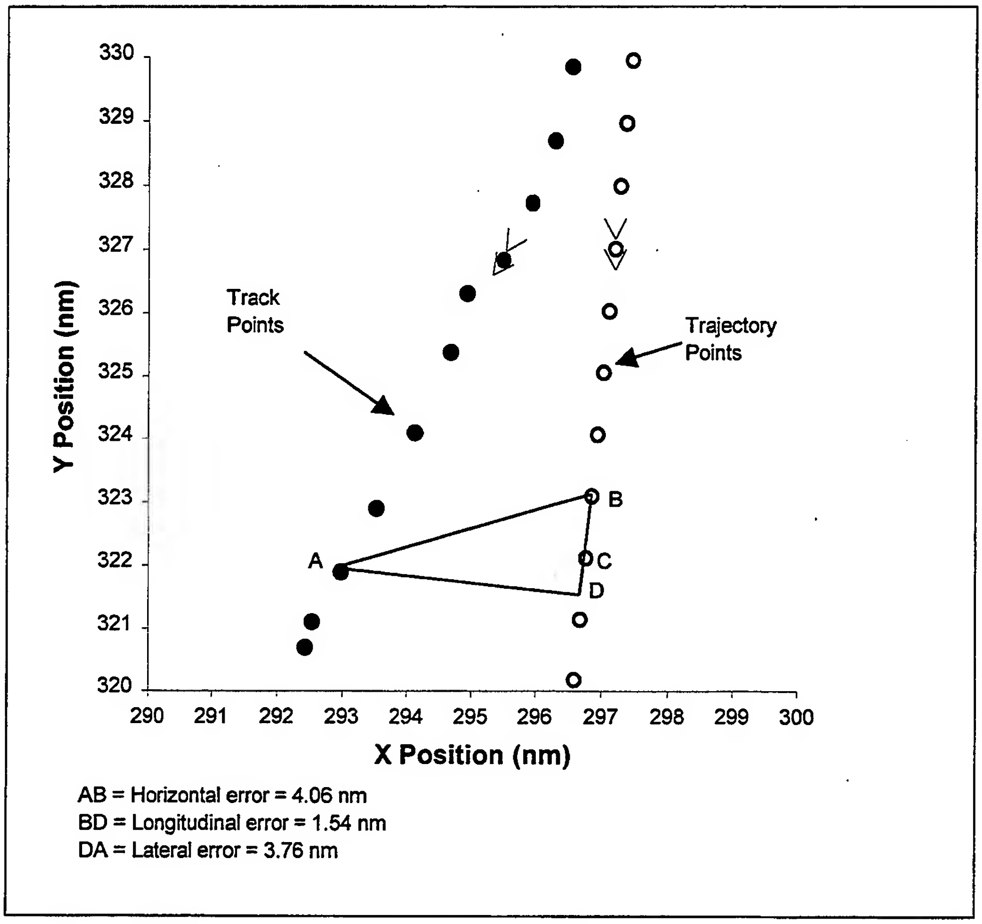


**Figure C.1-5: XY Error Geometry at 44750, Look ahead = 0**

**Table C.1-1: Trajectory Metrics (1 of 3)**[1]

| Sample Time | Traj Build Time | Look Ahead Time | Long Error | Lat Error | Vert Error |
|---|---|---|---|---|---|
| 44390 | 44363 | 0 | -1.02 | 0.69 | -67.00 |
| | | 300 | 1.35 | 1.30 | 455.93 |
| | | 600 | 6.78 | 8.17 | 293.11 |
| | | 900 | 7.32 | 6.02 | 0.00 |
| | | 1200 | 7.75 | 3.82 | 0.00 |
| | | 1500 | 7.89 | 1.67 | 0.00 |
| | | 1800 | 7.73 | -0.28 | 0.00 |
| 44510 | 44363 | 0 | -0.17 | 1.26 | -23.46 |
| | | 300 | 1.72 | 6.02 | 696.62 |
| | | 600 | 7.44 | 7.39 | 0.00 |
| | | 900 | 7.59 | 5.54 | 0.00 |
| | | 1200 | 7.67 | 2.73 | 0.00 |
| | | 1500 | 7.34 | 1.08 | 0.00 |
| | | 1800 | 8.67 | -1.09 | 0.00 |
| 44630 | 44363 | 0 | 1.03 | 0.73 | 259.11 |
| | | 300 | 5.83 | 8.51 | 644.83 |
| | | 600 | 7.29 | 6.28 | 0.00 |
| | | 900 | 7.42 | 4.58 | -67.00 |
| | | 1200 | 7.86 | 1.64 | 0.00 |
| | | 1500 | 7.64 | 0.20 | 0.00 |
| | | 1800 | 9.03 | -0.94 | 0.00 |
| 44750 | 44363 | 0 | 1.54 | 3.76 | 591.77 |
| | | 300 | 7.24 | 7.71 | 0.00 |
| | | 600 | 7.35 | 5.88 | 0.00 |
| | | 900 | 7.57 | 3.36 | 0.00 |
| | | 1200 | 7.14 | 1.41 | 0.00 |
| | | 1500 | 8.55 | -0.77 | 0.00 |
| | | 1800 | 9.36 | -0.99 | 0.00 |
| 44870 | 44363 | 0 | 1.86 | 8.32 | 773.20 |
| | | 300 | 7.73 | 6.75 | 0.00 |
| | | 600 | 7.28 | 5.18 | 0.00 |
| | | 900 | 7.80 | 2.19 | 0.00 |
| | | 1200 | 7.52 | 0.66 | 0.00 |
| | | 1500 | 8.80 | -0.91 | 0.00 |
| | | 1800 | 8.82 | -0.73 | 0.00 |

[1] In this chart, longitudinal and lateral error are reported in hundredths of nautical miles, and the vertical error is reported in hundredths of feet. The precision of the input HCS altitude data is reported to the nearest 100 feet, the apparent difference is simply an artifact of the track report processing.

Table C.1-1: Trajectory Metrics (2 of 3)

| Sample Time | Traj Build Time | Look Ahead Time | Long Error | Lat Error | Vert Error |
|---|---|---|---|---|---|
| 44990 | 44363 | 0 | 6.78 | 8.17 | 293.11 |
| | | 300 | 7.32 | 6.02 | 0.00 |
| | | 600 | 7.75 | 3.82 | 0.00 |
| | | 900 | 7.89 | 1.67 | 0.00 |
| | | 1200 | 7.73 | -0.28 | 0.00 |
| | | 1500 | 9.16 | -0.99 | 0.00 |
| | | 1800 | 9.46 | -0.99 | -33.00 |
| 45110 | 44363 | 0 | 7.44 | 7.39 | 0.00 |
| | | 300 | 7.59 | 5.54 | 0.00 |
| | | 600 | 7.67 | 2.73 | 0.00 |
| | | 900 | 7.34 | 1.08 | 0.00 |
| | | 1200 | 8.67 | -1.09 | 0.00 |
| | | 1500 | 9.49 | -0.94 | 0.00 |
| 45230 | 44363 | 0 | 7.29 | 6.28 | 0.00 |
| | | 300 | 7.42 | 4.58 | -67.00 |
| | | 600 | 7.86 | 1.64 | 0.00 |
| | | 900 | 7.64 | 0.20 | 0.00 |
| | | 1200 | 9.03 | -0.94 | 0.00 |
| | | 1500 | 9.30 | -0.80 | 0.00 |
| 45350 | 44363 | 0 | 7.35 | 5.88 | 0.00 |
| | | 300 | 7.57 | 3.36 | 0.00 |
| | | 600 | 7.14 | 1.41 | 0.00 |
| | | 900 | 8.55 | -0.77 | 0.00 |
| | | 1200 | 9.36 | -0.99 | 0.00 |
| 45470 | 44363 | 0 | 7.28 | 5.18 | 0.00 |
| | | 300 | 7.80 | 2.19 | 0.00 |
| | | 600 | 7.52 | 0.66 | 0.00 |
| | | 900 | 8.80 | -0.91 | 0.00 |
| | | 1200 | 8.82 | -0.73 | 0.00 |
| 45590 | 44363 | 0 | 7.75 | 3.82 | 0.00 |
| | | 300 | 7.89 | 1.67 | 0.00 |
| | | 600 | 7.73 | -0.28 | 0.00 |
| | | 900 | 9.16 | -0.99 | 0.00 |
| | | 1200 | 9.46 | -0.99 | -33.00 |

Table C.1-1: Trajectory Metrics (3 of 3)

| Sample Time | Traj Build Time | Look Ahead Time | Long Error | Lat Error | Vert Error |
|---|---|---|---|---|---|
| 45710 | 44363 | 0 | 7.67 | 2.73 | 0.00 |
| | | 300 | 7.34 | 1.08 | 0.00 |
| | | 600 | 8.67 | -1.09 | 0.00 |
| | | 900 | 9.49 | -0.94 | 0.00 |
| 45830 | 44363 | 0 | 7.86 | 1.64 | 0.00 |
| | | 300 | 7.64 | 0.20 | 0.00 |
| | | 600 | 9.03 | -0.94 | 0.00 |
| | | 900 | 9.30 | -0.80 | 0.00 |
| 45950 | 44363 | 0 | 7.14 | 1.41 | 0.00 |
| | | 300 | 8.55 | -0.77 | 0.00 |
| | | 600 | 9.36 | -0.99 | 0.00 |
| 46070 | 44363 | 0 | 7.52 | 0.66 | 0.00 |
| | | 300 | 8.80 | -0.91 | 0.00 |
| | | 600 | 8.82 | -0.73 | 0.00 |
| 46190 | 44363 | 0 | 7.73 | -0.28 | 0.00 |
| | | 300 | 9.16 | -0.99 | 0.00 |
| 46310 | 44363 | 0 | 8.67 | -1.09 | 0.00 |
| | | 300 | 9.49 | -0.94 | 0.00 |
| 46430 | 44363 | 0 | 9.03 | -0.94 | 0.00 |
| | | 300 | 9.30 | -0.80 | 0.00 |
| 46550 | 44363 | 0 | 9.36 | -0.99 | 0.00 |
| 46670 | 44363 | 0 | 8.82 | -0.73 | 0.00 |
| 46790 | 44363 | 0 | 9.46 | -0.99 | -33.00 |

## C.1.2 URET3

This example shows how trajectory errors can be large when a trajectory modeler produces a single, erroneous trajectory, and how modeling instantaneous turns affects the trajectory metrics. This flight was a general aviation aircraft twin jet Gulfstream that departed Dulles Airport (IAD) and returned via the Youngstown Ohio (YNG) and Charleston West Virginia (HVQ) VORTACs. The interpolated XY track data and route are shown in Figure C.1-6. This is the eastern side of ZID. The radar track started in the Cleveland ARTCC (ZOB) at 15:01:22 (54082 seconds). The track data was interpolated each 10 seconds over the interval from 15:01:30 (54090 seconds) through 15:34:20 (56060 seconds), a duration of 1970 seconds or 32.8 minutes. The aircraft was in level flight at Flight Level 450 for most of this interval, making a 100 degree turn at the Charleston VORTAC to head back to Dulles.

### C.1.2.1 Track Data

The HCS track data started with the aircraft in ZOB, at altitude approaching ZID, flying from the Youngstown VORTAC (YNG) to the Charleston VORTAC (HVG). The first two track reports had zero altitude and were discarded. There were 217 track reports. However, as the aircraft followed the Charleston transition to the Jasen1 STAR, the HCS lost altitude data when the aircraft was between the DILNN and FINKS fixes. After 15:34:22 there were no more altitude reports. The track was terminated at this point for analysis purposes. 166 reports remained to be used for analysis. During the period of no altitude data, the track was completely lost for 3408 seconds or 56.8 minutes. When the track was re-acquired, the ground speed was reported to be about 50 knots.

It was necessary to correct two of the 166 track reports by interpolation. The first was corrected because it reported the aircraft had not moved since its previous report. The second was corrected because it reported the aircraft was flying too slowly (270 knots) compared to its immediately previous speed of 417 knots.

### C.1.2.2 Trajectories

Figure C.1-7 presents the trajectories generated for this aircraft. The individual trajectories are identified by their build times in seconds. The arrowheads are placed at two minute intervals and mark the sampling times. The three trajectories, built before the track started at 53134, 53303, and 54058 seconds, were not sampled. The trajectory used for the first sample (54130) was built at the time the track started (54082 seconds). This trajectory began at the approximate current position of the aircraft and predicted it would return directly to Dulles Airport (see Figure C.1-8).

Since another trajectory was not calculated until 336 seconds later at 54418 seconds, trajectory metrics were calculated for three sample times using this trajectory. The aircraft was still in ZOB at each of these sample times. Because the track and trajectory were diverging, large errors were found at each measurement. The largest horizontal error at a look ahead time of zero seconds was 42.4 nautical miles at a sample time of 54370 seconds. In addition, the trajectory descended the aircraft as it got closer to the airport. Because the aircraft was actually in level flight a vertical error of 2200 feet was incurred at the last measurement on this trajectory (look ahead time of zero).

Four additional trajectories were used, for which there was close agreement between the actual track and the track predictions with one exception. This exception occurred at the Charleston VORTAC when the aircraft turned to return to Dulles and cut the inside of the corner (or flew by the waypoint). Since URET models instantaneous turns, the horizontal separation between track and trajectory exceeded four nautical miles. A sample was taken during the turn at 55330 seconds, which had a horizontal error of 2.2 nautical miles. Figure C.1-9 shows the actual

location of the aircraft, the predicted location of the aircraft, and the horizontal error for this measurement[2].

### *C.1.2.3 Metrics*

Table C.1-2 presents the trajectory metrics calculated for this aircraft. The longitudinal and lateral errors are in nautical miles; the vertical errors are in feet. As discussed in Section 2.5.1, a sample is taken 40 seconds after the start of track and then repeated each two minutes until the track ends, the trajectory ends, or the track leaves the center. At each sample time the distance between the track and trajectory was calculated at the current time and at look ahead times of zero and at 300 second or five minute increments into the future; resulting in look ahead times of 300, 600, 900, 1200, 1500, and 1800 seconds. This flight exited ZID at 15:28:20 (55700 seconds). From the table it can be seen that as the aircraft approached the center boundary, the metrics for fewer and fewer look ahead times were calculated.

As stated earlier, large errors are present at the first three samples times (54130, 54250, and 54370 seconds) when the trajectory with a build time of 54082 seconds was used. The errors are more representative starting with the fourth sample (54490 seconds).

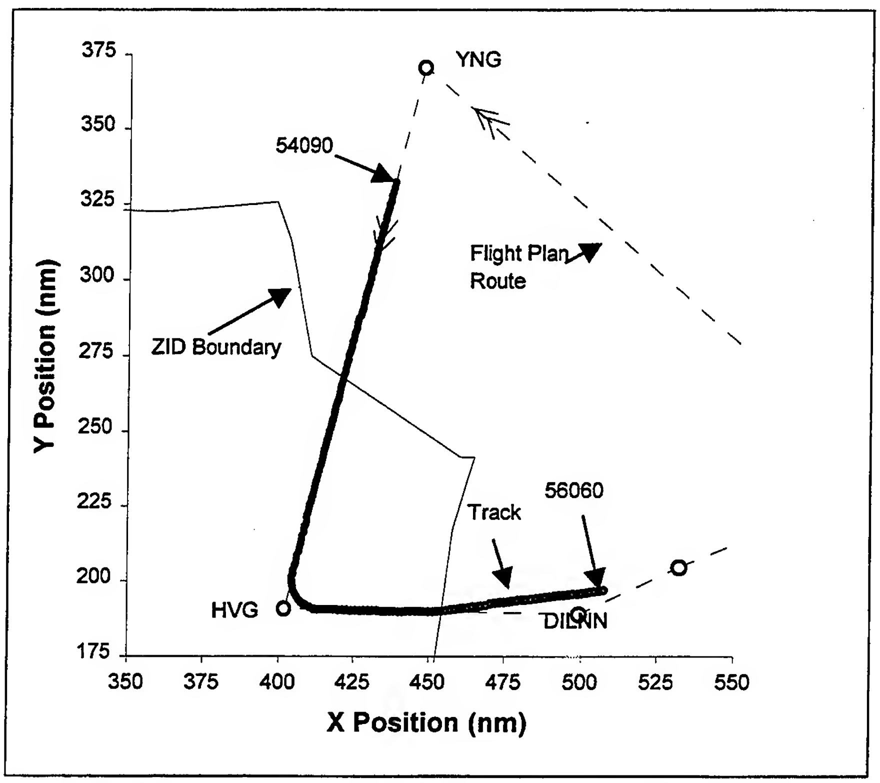


**Figure C.1-6: Interpolated Track and Route XY Position**

[2] The longitudinal error is normally the along track error, but for a short time just after a sharp turn the lateral error becomes the along track error.

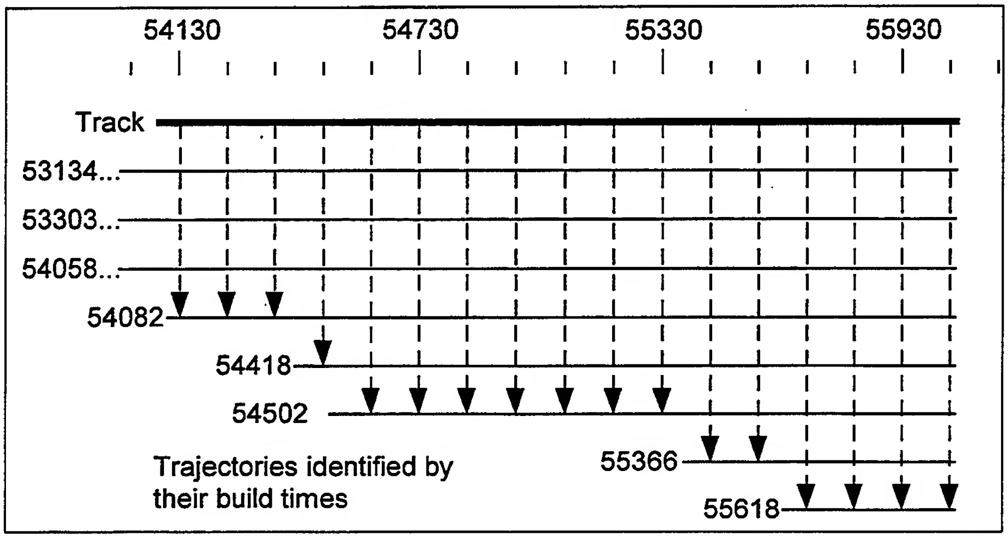


**Figure C.1.7: Sampled Trajectories**

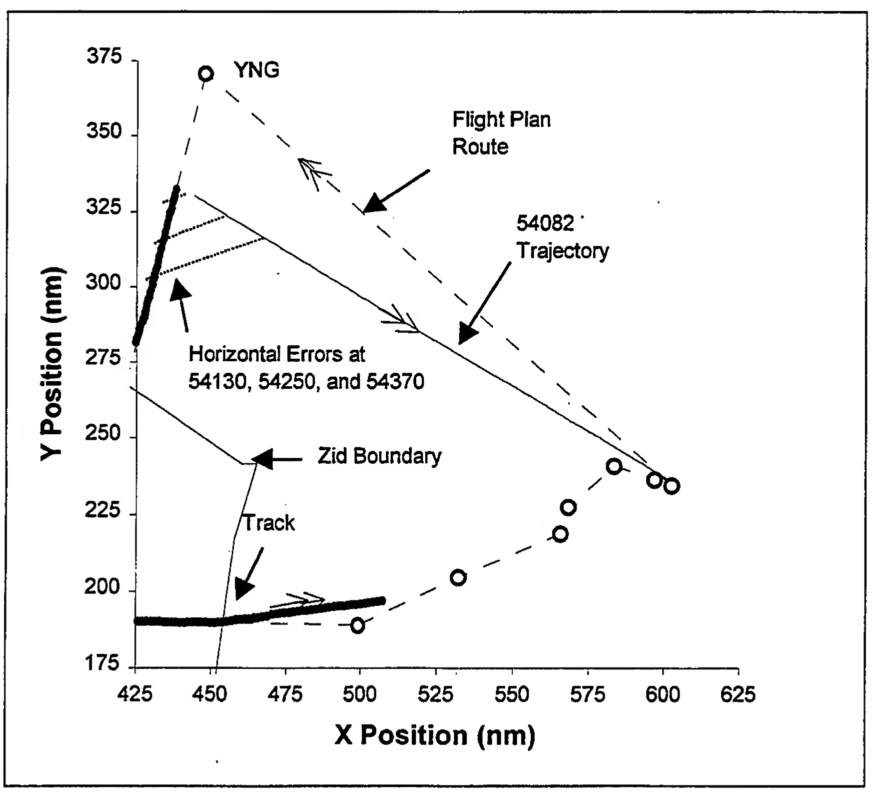


**Figure C.1.8: Sampled Points Along 54082 Trajectory**

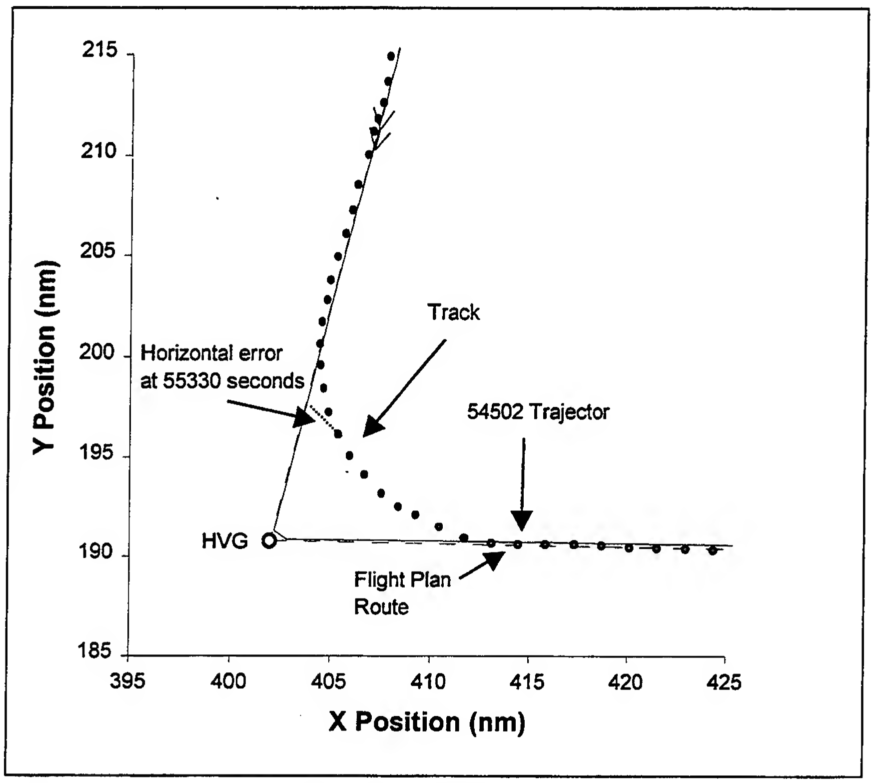


**Figure C.1-9: Sampled Point During Turn**

Table C.1-2: Trajectory Metrics

| Sample Time | Traj Build Time | Look Ahead Time | Long Error | Lat Error | Vert Error |
|---|---|---|---|---|---|
| 54130 | 54082 | 0 | -4.14 | 7.19 | 0.00 |
| | | 300 | -32.58 | 38.93 | 3922.04 |
| | | 600 | -58.15 | 71.88 | 14420.54 |
| | | 900 | -84.79 | 103.76 | 22300.08 |
| | | 1200 | -109.33 | 134.87 | 32507.66 |
| | | 1500 | -99.82 | 120.34 | 38907.87 |
| 54250 | 54082 | 0 | -16.18 | 19.99 | 0.00 |
| | | 300 | -42.87 | 52.50 | 8395.25 |
| | | 600 | -68.72 | 84.70 | 17631.89 |
| | | 900 | -95.77 | 115.83 | 25785.61 |
| | | 1200 | -107.08 | 132.88 | 35100.00 |
| 54370 | 54082 | 0 | -27.53 | 32.23 | 2188.53 |
| | | 300 | -53.10 | 65.49 | 12376.71 |
| | | 600 | -79.36 | 97.45 | 20728.90 |
| | | 900 | -106.71 | 129.48 | 30746.50 |
| | | 1200 | -102.37 | 124.60 | 37473.73 |
| 54490 | 54418 | 0 | 1.67 | 0.19 | 0.00 |
| | | 300 | 7.48 | 0.17 | 100.00 |
| | | 600 | 12.63 | 0.38 | 0.00 |
| | | 900 | 14.50 | -7.99 | 0.00 |
| | | 1200 | 36.58 | 0.22 | 100.00 |
| 54610 | 54502 | 0 | 0.37 | 0.15 | 100.00 |
| | | 300 | 0.78 | 0.22 | 100.00 |
| | | 600 | 0.38 | 0.11 | 100.00 |
| | | 900 | 8.91 | 0.23 | 0.00 |
| 54730 | 54502 | 0 | 0.59 | 0.08 | 0.00 |
| | | 300 | 0.84 | 0.26 | 0.00 |
| | | 600 | 0.99 | -1.93 | 100.00 |
| | | 900 | 9.14 | 0.35 | 0.00 |
| 54850 | 54502 | 0 | 0.73 | 0.23 | 0.00 |
| | | 300 | 0.31 | 0.06 | 0.00 |
| | | 600 | 8.73 | 0.10 | 100.00 |
| 54970 | 54502 | 0 | 0.84 | 0.26 | 0.00 |
| | | 300 | 1.31 | 0.26 | 0.00 |
| | | 600 | 8.99 | 0.36 | 200.00 |
| 55090 | 54502 | 0 | 0.85 | 0.38 | 0.00 |
| | | 300 | 6.85 | -4.69 | 0.00 |
| | | 600 | 9.68 | 0.17 | 1553.77 |
| 55210 | 54502 | 0 | 0.38 | 0.11 | 100.00 |
| | | 300 | 8.91 | 0.23 | 0.00 |
| 55330 | 54502 | 0 | 0.99 | -1.93 | 100.00 |
| | | 300 | 9.14 | 0.35 | 0.00 |
| 55450 | 55366 | 0 | -1.16 | 0.10 | 100.00 |
| 55570 | 55366 | 0 | -0.75 | 0.36 | 200.00 |
| 55690 | 55618 | 0 | 0.14 | -0.06 | 100.00 |

## C.2 CTAS Observations

### C.2.1 CTAS2

This example shows how trajectory errors can increase rapidly when updated trajectories are no longer available. In this example the aircraft flew faster than predicted. This resulted in large longitudinal errors when the trajectories were not updated. The lateral errors were minimal while the aircraft flew a straight line track, but a sharp turn on the SASIE SID caused a large lateral error briefly.

#### C.2.1.1 Track Data

The aircraft, a Piper Malibu, flew from the Beech factory in Wichita to the Addison airport near Dallas. The original Flight Plan routed the aircraft via the VORTACs at Pioneer (at Ponca City) (PER), Will Rogers (at Oklahoma City) (IRW), and Ardmore (ADM). Amendments rerouted the flight to the Bonham (BYP) VORTAC and the SASIE STAR, by passing the IRW and ADM VORTACs.

The aircraft was already at altitude (21,000 feet) when it was picked up by ZFW. The track data recovered for this aircraft began at 20:36:49 (74209 seconds) and ended at 21:37:13 (77833). This data was interpolated each ten seconds over the interval from 20:36:50 (74210 seconds) through 21:37:10 (77830 seconds), a duration of 3620 seconds, or approximately one hour. Figure C.2-1 presents a plot of the interpolated XY track data and Figure C.2-2 presents the interpolated altitude track data plotted against track time. This track began between the Pioneer and Will Rogers VORTACs in the Kansas City ARTCC (ZKC). Shortly after the start of the track, the Flight Plan was amended to fly to Addison Airport via the Bonham (BYP) VORTAC instead of the Will Rogers and Ardmore VORTACs. Also the aircraft was redirected to SASIE and never actually flew to BYP.

C.2.1.1.1 Time Adjustment

The time stamps assigned by the CTAS recording operation were first rounded to the nearest second and then adjusted by adding or subtracting seconds so the track reports all occurred at intervals of 12 seconds or at intervals of integer multiples of 12 seconds. Table C.2-1 shows the counts of the time intervals after rounding and before adjustment, after adjustment, and after correction processing. After the time adjustment there were 15 24-second intervals or 15 missing position reports. They were inserted by interpolation. There was one stationary point in the input data; it was replaced, also by interpolation.

#### C.2.1.2 Trajectories

Figure C.2-3 presents the track time line and the time lines for 15 of the 116 trajectories recovered for this aircraft. The time line is labeled “Track”. Each of the trajectories is labeled with the trajectory's build time. The trajectory sampled for the starting sample time (74250 seconds) was the 74244 trajectory, since this was the latest trajectory prior to the sample time. The sampling interval used in this study was 120 seconds. The trajectory used for the next sample time (74250+120 = 74370 seconds) was the 74363 trajectory. This process of associating the last valid trajectory with a sample time was continued for the entire track. As a result 13 of the 116 trajectories were used: 74244, 74363, 74484, 74604, 74723, 74844, 74963, 75083, 75203, 75323, 75443, 75565, and 75647.

The first two trajectories follow the Flight Plan as it was originally filed to the Will Rogers VORTAC and then proceed to join the route from the current position to the Bonham VORTAC. Subsequent trajectories follow the Flight Plan as it was amended.

### *C.2.1.3 Metrics*

The predictions, for a zero look ahead time, closely match the actual flight until the 75647 trajectory, which was the last trajectory CTAS provided. The predicted ground speed was about 50 knots less than the actual ground speed for each trajectory. As long as the trajectories kept getting updated, the position error for the zero look ahead time remains small. But as the track diverged longitudinally from the trajectory, as the trajectory got older, large longitudinal errors were calculated. Figure C.2-4 provides a plot of the values of the X coordinates of the track and the trajectory (the 75647 trajectory), and shows the X component of the horizontal error increasing with time. Similarly, Figure C.2-5 shows the Y component of the horizontal error increasing with time. These figures show the trajectory's XY data is accurate but displaced in time.

Figure C.2-6 is a plot of altitude vs time for the track and the trajectory. The predicted Top of Descent (TOD) is in error in all of the predicted trajectories by about 74 nautical miles. This causes large altitude errors in the descent phase of the flight.

Table C.2-2 presents the trajectory metrics calculated for this aircraft.

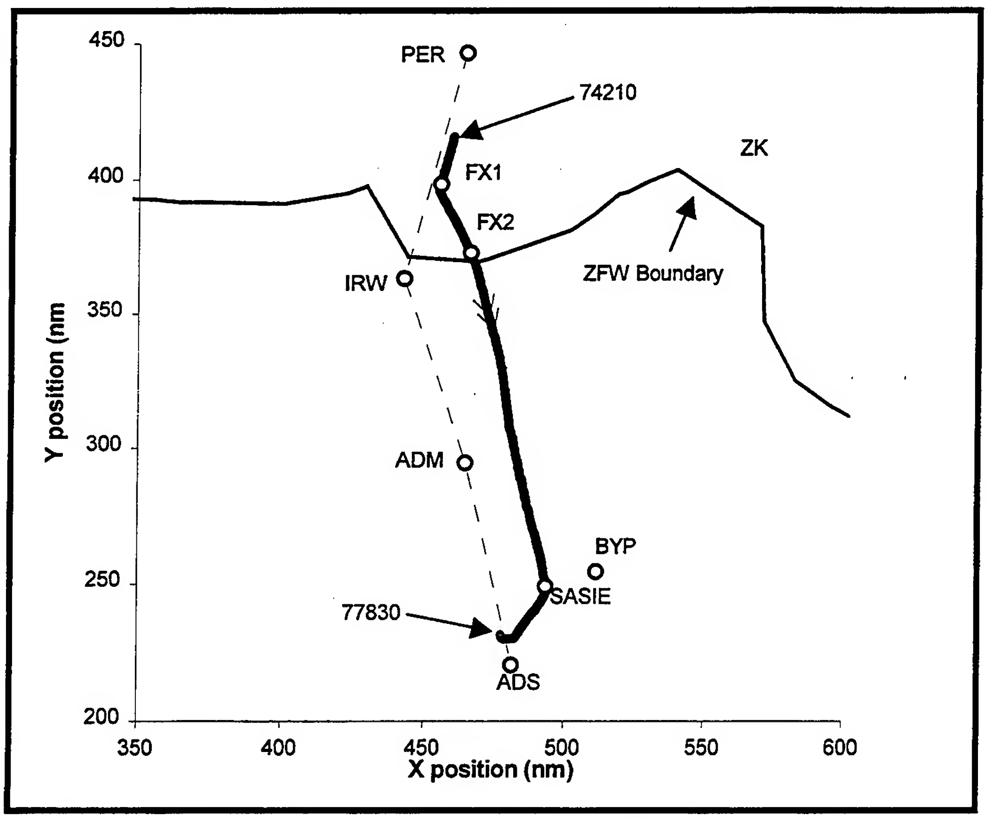


**Figure C.2-1: Track XY Position**

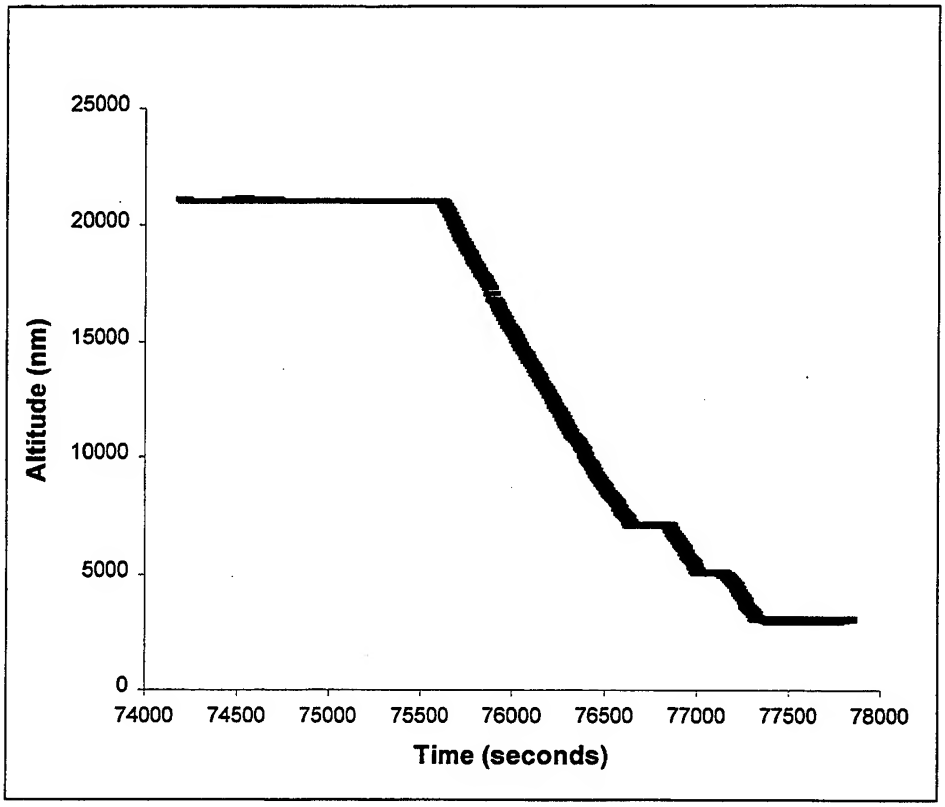


**Figure C.2-2: Track Altitude**

**Table C.2-1: Track Report Time Intervals for CTAS 2**

| Gap Size (Seconds) | Count Before Adjustment | Count After Adjustment | Count After Processing |
|---|---|---|---|
| 11 | 52 | 0 | 0 |
| 12 | 164 | 272 | 302 |
| 13 | 56 | 0 | 0 |
| 23 | 3 | 0 | 0 |
| 24 | 11 | 15 | 0 |
| 25 | 1 | 0 | 0 |

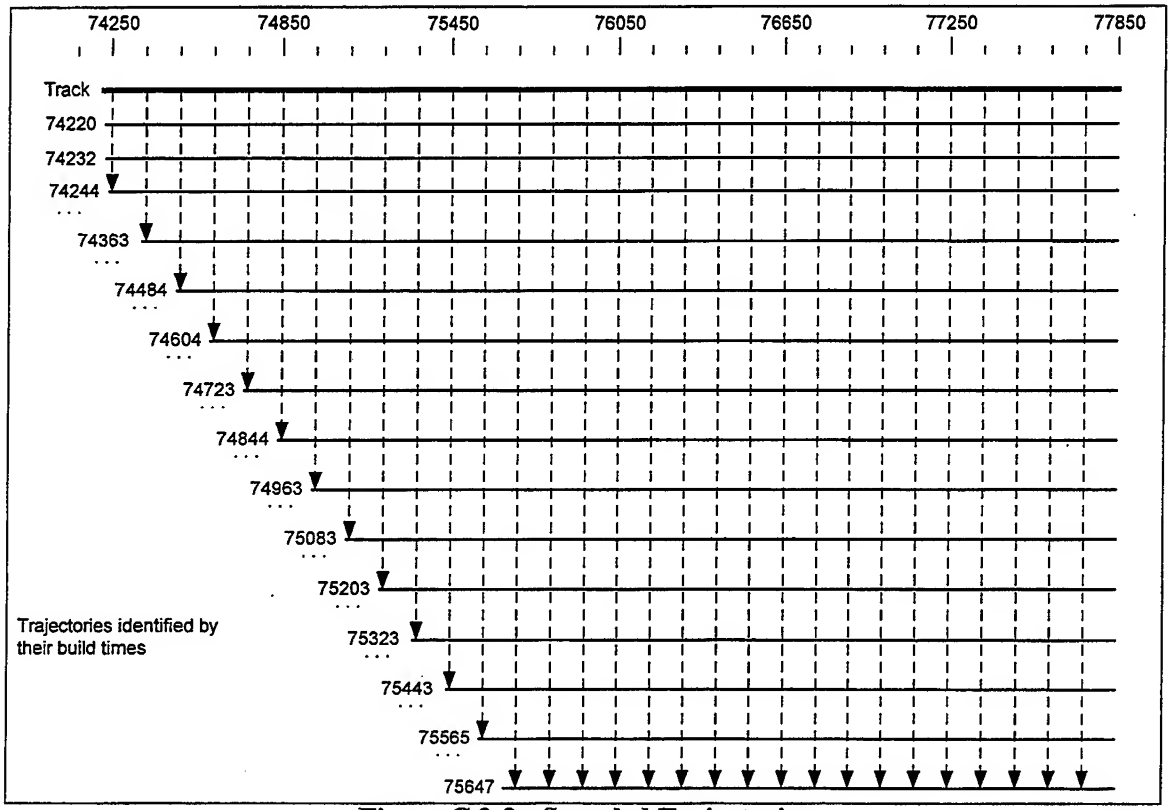


**Figure C.2-3: Sampled Trajectories**

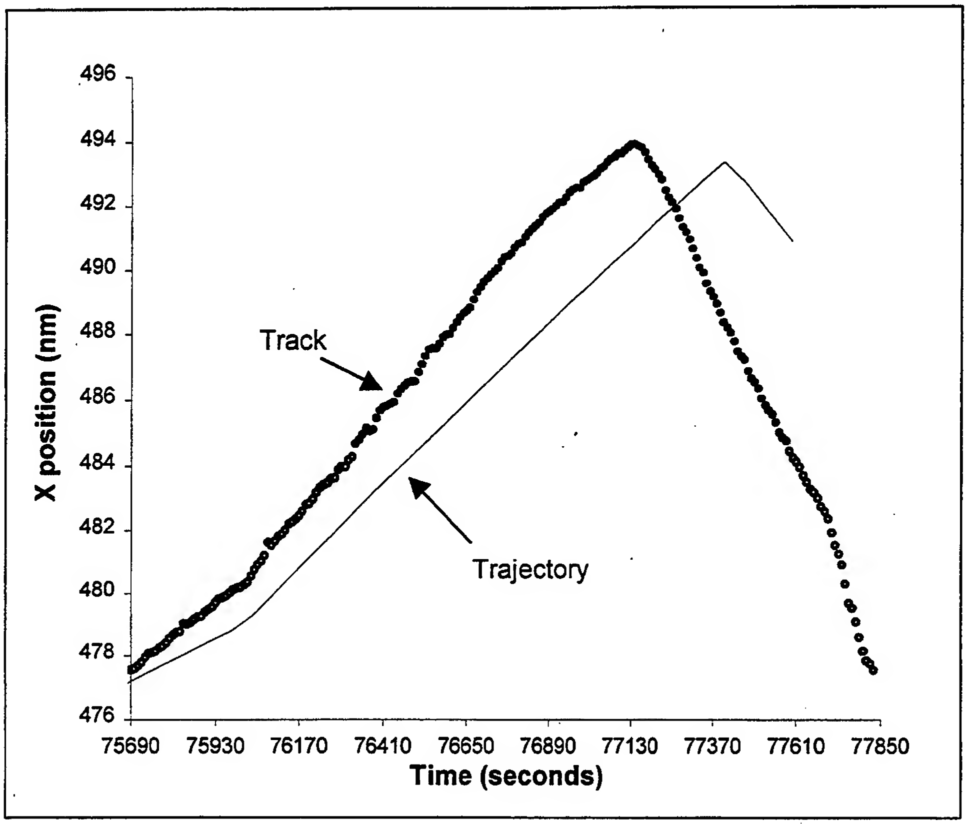


**Figure C.2-4: Track X and 75647 Trajectory X**

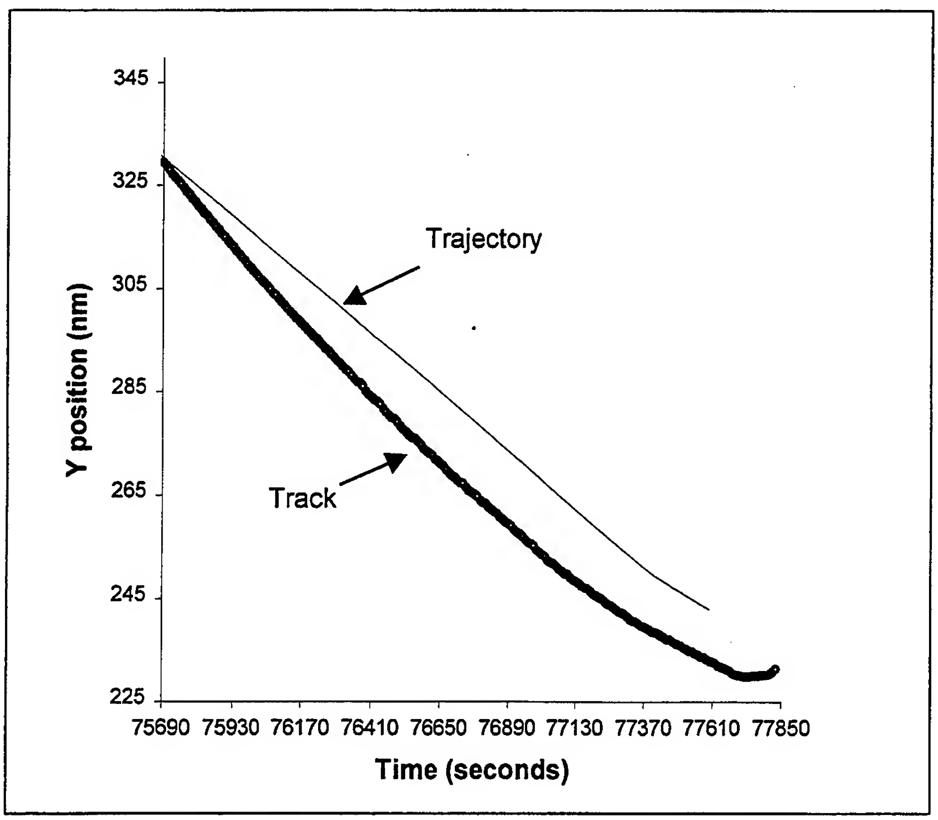


**Figure C.2-5: Track Y and 75647 Trajectory Y**

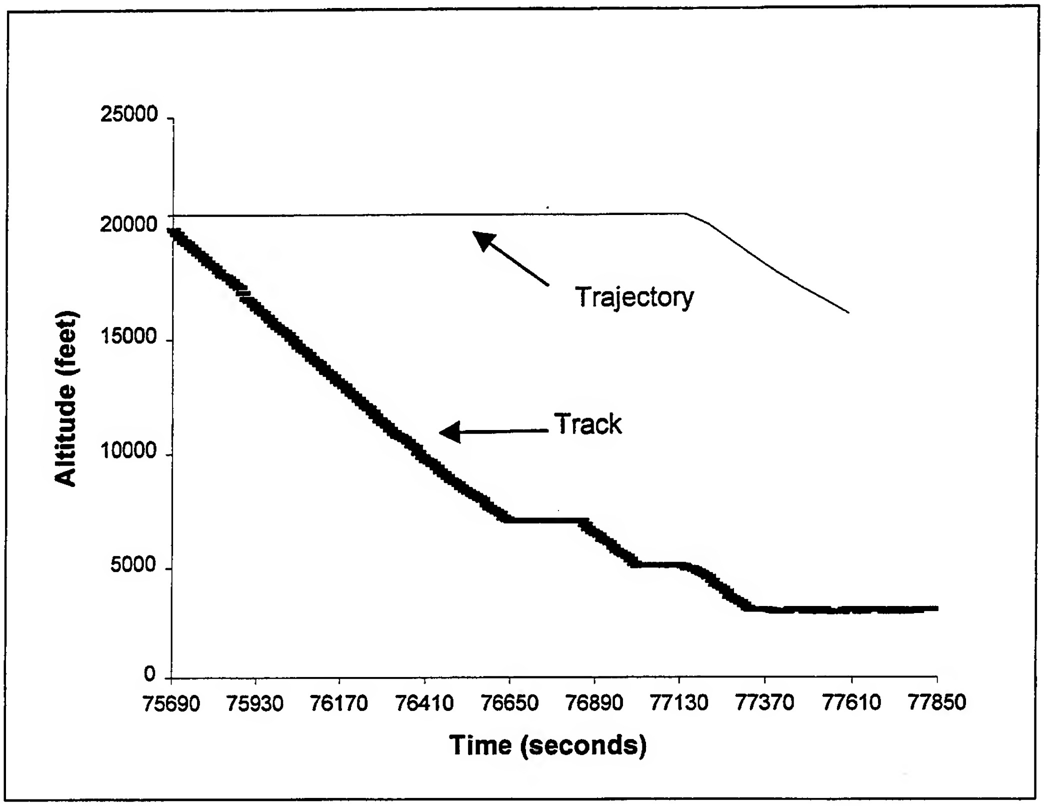


**Figure C.2-6: Track and 75647 Trajectory Altitude vs Time**

**Table C.2-2: Trajectory Metrics (1 of 4)[3]**

| Sample Time | Traj Build Time | Look Ahead Time | Long Error | Lat Error | Vert Error |
|---|---|---|---|---|---|
| 74250 | 74244 | 0 | 0.01 | -0.03 | 0.00 |
| | | 300 | 3.49 | -0.82 | 100.00 |
| | | 600 | 5.05 | -13.08 | 0.00 |
| | | 900 | 7.59 | -25.29 | 0.00 |
| | | 1200 | 11.24 | -35.63 | 0.00 |
| | | 1500 | 39.59 | 0.01 | -1983.00 |
| | | 1800 | 39.76 | 11.36 | -6283.00 |
| 74370 | 74363 | 0 | -0.02 | -0.01 | 0.00 |
| | | 300 | 3.15 | -4.54 | 0.00 |
| | | 600 | 4.56 | -18.17 | 0.00 |
| | | 900 | 7.69 | -29.31 | 0.00 |
| | | 1200 | 37.60 | -6.36 | 0.00 |
| | | 1500 | 38.23 | 4.74 | -3542.00 |
| | | 1800 | 38.17 | 15.18 | -7942.00 |

[3] In this chart, longitudinal and lateral error are reported in hundredths of nautical miles, and the vertical error is reported in hundredths of feet. The precision of the input HCS altitude data is reported to the nearest 100 feet, the apparent difference is simply an artifact of the track report processing.

Table C.2-2: Trajectory Metrics (2 of 4)

| Sample Time | Traj Build Time | Look Ahead Time | Long Error | Lat Error | Vert Error |
|---|---|---|---|---|---|
| 74490 | 74484 | 0 | 0.02 | -0.04 | 0.00 |
| | | 300 | 1.98 | -9.94 | 0.00 |
| | | 600 | 3.95 | -23.03 | 0.00 |
| | | 900 | 8.51 | -33.32 | 0.00 |
| | | 1200 | 36.14 | -2.42 | -1083.00 |
| | | 1500 | 36.55 | 9.50 | -5442.00 |
| | | 1800 | 36.19 | 19.00 | -9642.00 |
| 74610 | 74604 | 0 | 0.00 | -0.02 | 0.00 |
| | | 300 | 3.01 | -0.66 | 0.00 |
| | | 600 | 6.01 | 0.72 | 0.00 |
| | | 900 | 8.90 | 3.03 | 0.00 |
| | | 1200 | 12.41 | 6.45 | -2783.00 |
| | | 1500 | 15.11 | 10.67 | -7083.00 |
| | | 1800 | 16.87 | 13.69 | -11242.00 |
| 74730 | 74723 | 0 | -0.05 | -0.06 | 0.00 |
| | | 300 | 4.12 | -0.32 | 0.00 |
| | | 600 | 7.94 | 1.76 | 0.00 |
| | | 900 | 11.80 | 3.91 | -183.00 |
| | | 1200 | 16.84 | 8.33 | -4583.00 |
| | | 1500 | 19.91 | 11.95 | -8783.00 |
| | | 1800 | 22.29 | 14.81 | -12642.00 |
| 74850 | 74844 | 0 | 0.01 | -0.01 | 0.00 |
| | | 300 | 4.23 | 0.26 | 0.00 |
| | | 600 | 8.16 | 2.64 | 0.00 |
| | | 900 | 12.52 | 5.53 | -1983.00 |
| | | 1200 | 16.84 | 9.90 | -6283.00 |
| | | 1500 | 19.66 | 13.14 | -10342.00 |
| | | 1800 | 20.81 | 15.74 | -13900.00 |
| 74970 | 74963 | 0 | -0.03 | -0.09 | 0.00 |
| | | 300 | 4.44 | -1.41 | 0.00 |
| | | 600 | 8.96 | -1.85 | 0.00 |
| | | 900 | 14.44 | -0.60 | -3542.00 |
| | | 1200 | 18.96 | 0.38 | -7942.00 |
| | | 1500 | 22.40 | 0.26 | -11983.00 |
| | | 1800 | 23.26 | -0.31 | -13900.00 |
| 75090 | 75083 | 0 | -0.02 | -0.04 | 0.00 |
| | | 300 | 4.73 | -1.82 | 0.00 |
| | | 600 | 9.47 | -1.79 | -1083.00 |
| | | 900 | 15.12 | 0.19 | -5442.00 |
| | | 1200 | 18.90 | 0.33 | -9642.00 |
| | | 1500 | 21.64 | 0.21 | -13342.00 |
| | | 1800 | 21.68 | -0.54 | -14442.00 |

**Table C.2-2: Trajectory Metrics (3 of 4)**

| Sample Time | Traj Build Time | Look Ahead Time | Long Error | Lat Error | Vert Error |
|---|---|---|---|---|---|
| 75210 | 75203 | 0 | -0.01 | -0.08 | 0.00 |
| | | 300 | 5.00 | -1.84 | 0.00 |
| | | 600 | 10.28 | -1.02 | -2783.00 |
| | | 900 | 15.08 | 0.18 | -7083.00 |
| | | 1200 | 18.70 | 0.15 | -11242.00 |
| | | 1500 | 20.33 | -0.28 | -13900.00 |
| | | 1800 | 20.18 | -0.25 | -15900.00 |
| 75330 | 75323 | 0 | 0.08 | 0.00 | 0.00 |
| | | 300 | 4.56 | -1.21 | -183.00 |
| | | 600 | 10.62 | -0.31 | -4583.00 |
| | | 900 | 14.77 | 0.19 | -8783.00 |
| | | 1200 | 17.94 | 0.10 | -12642.00 |
| | | 1500 | 18.44 | -0.47 | -13900.00 |
| | | 1800 | 17.88 | -0.17 | -15900.00 |
| 75450 | 75443 | 0 | 0.01 | -0.04 | 0.00 |
| | | 300 | 5.14 | -0.83 | -1983.00 |
| | | 600 | 10.56 | -0.01 | -6283.00 |
| | | 900 | 14.33 | 0.18 | -10342.00 |
| | | 1200 | 16.28 | 0.04 | -13900.00 |
| | | 1500 | 16.58 | -0.44 | -15242.00 |
| | | 1800 | 14.36 | 2.51 | -16048.00 |
| 75570 | 75565 | 0 | 0.05 | -0.01 | 0.00 |
| | | 300 | 5.81 | -0.44 | -3542.00 |
| | | 600 | 10.50 | 0.26 | -7942.00 |
| | | 900 | 13.94 | 0.27 | -11983.00 |
| | | 1200 | 14.82 | -0.38 | -13900.00 |
| | | 1500 | 14.86 | -0.30 | -15900.00 |
| | | 1800 | 10.77 | 6.28 | -15247.46 |
| 75690 | 75647 | 0 | 0.83 | -0.28 | -683.00 |
| | | 300 | 7.11 | -0.08 | -5042.00 |
| | | 600 | 11.01 | 0.71 | -9242.00 |
| | | 900 | 13.96 | 0.26 | -12942.00 |
| | | 1200 | 14.22 | -0.53 | -14042.00 |
| | | 1500 | 13.32 | 0.89 | -15493.45 |
| | | 1800 | 11.92 | 1.45 | -14068.17 |
| 75810 | 75647 | 0 | 3.56 | -0.39 | -2383.00 |
| | | 300 | 8.81 | 0.33 | -6683.00 |
| | | 600 | 12.57 | 0.46 | -10842.00 |
| | | 900 | 14.41 | -0.20 | -13500.00 |
| | | 1200 | 14.47 | -0.34 | -15500.00 |
| | | 1500 | 11.52 | 4.35 | -15614.63 |
| 75930 | 75647 | 0 | 6.02 | -0.44 | -4183.00 |
| | | 300 | 10.29 | 0.51 | -8383.00 |
| | | 600 | 13.64 | 0.21 | -12242.00 |
| | | 900 | 14.35 | -0.49 | -13500.00 |
| | | 1200 | 14.01 | -0.25 | -15500.00 |
| | | 1500 | 11.85 | 2.07 | -14591.77 |

Table C.2-2: Trajectory Metrics (4 of 4)

| Sample Time | Traj Build Time | Look Ahead Time | Long Error | Lat Error | Vert Error |
|---|---|---|---|---|---|
| 76050 | 75647 | 0 | 7.94 | 0.38 | -5883.00 |
| | | 300 | 11.82 | 0.65 | -9942.00 |
| | | 600 | 13.99 | 0.10 | -13500.00 |
| | | 900 | 14.48 | -0.51 | -14842.00 |
| | | 1200 | 12.44 | 2.44 | -15565.91 |
| | | 1500 | 11.73 | 1.91 | -13523.00 |
| 76170 | 75647 | 0 | 9.55 | 0.55 | -7542.00 |
| | | 300 | 13.16 | 0.45 | -11583.00 |
| | | 600 | 14.24 | -0.38 | -13500.00 |
| | | 900 | 14.47 | -0.33 | -15500.00 |
| | | 1200 | 10.43 | 6.25 | -15157.46 |
| 76290 | 75647 | 0 | 11.01 | 0.71 | -9242.00 |
| | | 300 | 13.96 | 0.26 | -12942.00 |
| | | 600 | 14.22 | -0.53 | -14042.00 |
| | | 900 | 13.32 | 0.89 | -15493.45 |
| | | 1200 | 11.92 | 1.45 | -14068.17 |
| 76410 | 75647 | 0 | 12.57 | 0.46 | -10842.00 |
| | | 300 | 14.41 | -0.20 | -13500.00 |
| | | 600 | 14.47 | -0.34 | -15500.00 |
| | | 900 | 11.52 | 4.35 | -15614.63 |
| 76530 | 75647 | 0 | 13.64 | 0.21 | -12242.00 |
| | | 300 | 14.35 | -0.49 | -13500.00 |
| | | 600 | 14.01 | -0.25 | -15500.00 |
| | | 900 | 11.85 | 2.07 | -14591.77 |
| 76650 | 75647 | 0 | 13.99 | 0.10 | -13500.00 |
| | | 300 | 14.48 | -0.51 | -14842.00 |
| | | 600 | 12.44 | 2.44 | -15565.91 |
| | | 900 | 11.73 | 1.91 | -13523.00 |
| 76770 | 75647 | 0 | 14.24 | -0.38 | -13500.00 |
| | | 300 | 14.47 | -0.33 | -15500.00 |
| | | 600 | 10.43 | 6.25 | -15157.46 |
| 76890 | 75647 | 0 | 14.22 | -0.53 | -14042.00 |
| | | 300 | 13.32 | 0.89 | -15493.45 |
| | | 600 | 11.92 | 1.45 | -14068.17 |
| 77010 | 75647 | 0 | 14.47 | -0.34 | -15500.00 |
| | | 300 | 11.52 | 4.35 | -15614.63 |
| 77130 | 75647 | 0 | 14.01 | -0.25 | -15500.00 |
| | | 300 | 11.85 | 2.07 | -14591.77 |
| 77250 | 75647 | 0 | 12.44 | 2.44 | -15565.91 |
| | | 300 | 11.73 | 1.91 | -13523.00 |
| 77370 | 75647 | 0 | 10.43 | 6.25 | -15157.46 |
| 77490 | 75647 | 0 | 11.92 | 1.45 | -14068.17 |

### C.2.2 CTAS3

This example illustrates how the lack of pilot intent information in the form of an ATC clearance can cause large trajectory prediction errors in the horizontal and vertical dimensions. It also shows how the CTAS trajectory synthesis can, for rather long periods (e.g. two to 10 minutes), not update the trajectory prediction. When the trajectory did not get updated, the trajectory prediction errors became very large: to 34 nautical miles in the horizontal to 19,000 feet in the vertical.

#### C.2.2.1 Track Data

The aircraft, Bae125, filed a Flight Plan from Meacham Field (FTW) and return, flying out to Abilene using the King3 for departure and Slugg4 for arrival back at FTW. However, the aircraft did not follow the filed Flight Plan. It climbed out to the west northwest to an altitude of 39,000 feet, made a big looping turn and came back to FTW.

The track data used for this aircraft began at the time 22:22:28 (80548 seconds) and was interpolated each ten seconds over the interval from 22:22:30 (80550 seconds) through 22:50:10 (82210 seconds). During this period the HCS supplied 240 track reports for this aircraft.

##### C.2.2.1.1 Time Adjustment

The time stamps assigned by CTAS were first rounded to the nearest second and then adjusted to 12 second intervals or to intervals of multiples of 12 seconds. Table C.2-3 shows the time intervals after rounding and before adjustment, after adjustment, and after correction processing.

**Table C.2-3: Track Report Time Intervals for CTAS3**

| Gap Size (Seconds) | Count Before Adjustment | Count After Adjustment | Count After Processing |
|---|---|---|---|
| 11 | 45 | 0 | 0 |
| 12 | 139 | 233 | 232 |
| 13 | 49 | 0 | 0 |
| 23 | 2 | 0 | 0 |
| 24 | 4 | 6 | 0 |
| 132 | 0 | 0 | 1 |

After the time adjustment there remained six gaps in the track data where one report was missing. All of these gaps were patched by interpolation. That is, six track reports were added to the track to fill in these small gaps. There were two instances in the track where the aircraft did not move between radar position reports. The XYZ values for these two track reports were replaced with interpolated values. There was one instance where the aircraft moved between reports, but for only a short distance (0.08 nautical miles). The XYZ values were replaced here also. The first two track reports were discarded because the altitude changed from 41,000 feet to 5300 feet. In one place in the track, adjacent track reports were inconsistent and the attempt to bridge the gap failed. Ten track reports were dropped and the track was re-initialized. Dropping the reports created a gap of 132 seconds in the track data. The track report correction processing deleted the first two reports, added six interpolated reports, filled the six 24 second gaps, and deleted 10 reports where the data was inconsistent. As a result, the 240 track reports, after correction processing, became 234 reports. The track as corrected then had one 132 second gap. In this study no more measurements are made on the track after such a break.

Figure C.2-7 presents a plot of the interpolated XY track data and the route as specified by the FP record. Figure C.2-8 presents the interpolated altitude track data plotted against time. The flight

plan indicates that the pilot's intent was to depart from Meacham Field (FTW), fly out to the Abilene fix (ABI) using the King3 departure and then return to FTW using the Slugg4 arrival. However, the recorded track data shows that this aircraft flew a route climbing to the northwest to an altitude of 39,000 feet, then made a clockwise turn and returned to FTW. Most likely, once the aircraft departed, ATC verbally allowed him to fly this new route, but CTAS had no knowledge of the route change. This led to large errors in the trajectory predictions.

#### C.2.3.2 Trajectories

Figure C.2-9 presents the track time line (labeled "Track") and the time line for 27 of the 41 trajectories recovered for this aircraft. Each of the trajectories is labeled with the trajectory's build time. The first sampling of the trajectory accuracy is shown in Figure C.2-9 by an arrow drawn from the track time line to the latest trajectory available at that sample time. The first sample starts 40 seconds after the time of the initial interpolated track, which in this example was 80590 seconds.

The trajectory sampled for the starting sample time (time = 80590 seconds) was the 80583 trajectory, since this was the latest trajectory available prior to the sample time. The first four trajectories are not used, since there was no track data available to associate these early trajectories. The sampling interval used in this study was 120 seconds. The trajectory used for the next sample time (time = 80590+120 = 80710 seconds) was also the 80583 trajectory, as it was until the sampling time of 81310 when the 81303 trajectory began to be used. This process of associating the last valid trajectory with a sample time was continued for the entire track. As a result six of the 41 trajectories were used: 80583, 81303, 81615, 81890, 82023 and 82119. The remaining trajectories were not used in the study since they were created for track points after the last available track point.

#### C.2.3.3 Metrics

The XY plots of these six trajectories are shown in Figure C.2-10 along with the interpolated track data. CTAS initially predicted a flight path following the Flight Plan. It then gave up on following the Flight Plan and predicted a series of return paths, each returning to FTW.

Besides the error due to the re-routing of this aircraft, this example illustrates a second, perhaps related, error source. Normally a CTAS trajectory is captured for each track point, but for this aircraft there were three time gaps where trajectories were not updated. The first gap occurred for 624 seconds between the 80583 and 81207 trajectories, the second occurred for 253 seconds between the 81303 and 81556 trajectories, and the third occurred for 213 seconds between the 81615 and 81818 trajectories.

Three of the 14 error measurements with a look ahead time of zero seconds were produced from three different sample trajectories (i.e. the 80583, 81303, and 81615 trajectories) with ages of 607, 247, and 175 seconds. These samples have horizontal errors of 14, 34, and 20 nautical miles and vertical errors of 18,900, 14,500, and 3,600 feet, respectively

The significance of these gaps is also shown in Figure C.2-11, which shows plots of the interpolated track XY and the uninterpolated trajectory XY position points for the 80583 trajectory. This figure also identifies the points at which trajectory metrics were calculated for sample time = 80590 seconds at look ahead times of zero, 300, 600, 900, 1200, and 1500. Figure C.2-12 shows the vertical trajectory metrics for the sample points on the 80583 trajectory. These metrics are presented, along with all the trajectory metrics calculated for this aircraft, in Table C.2-4.

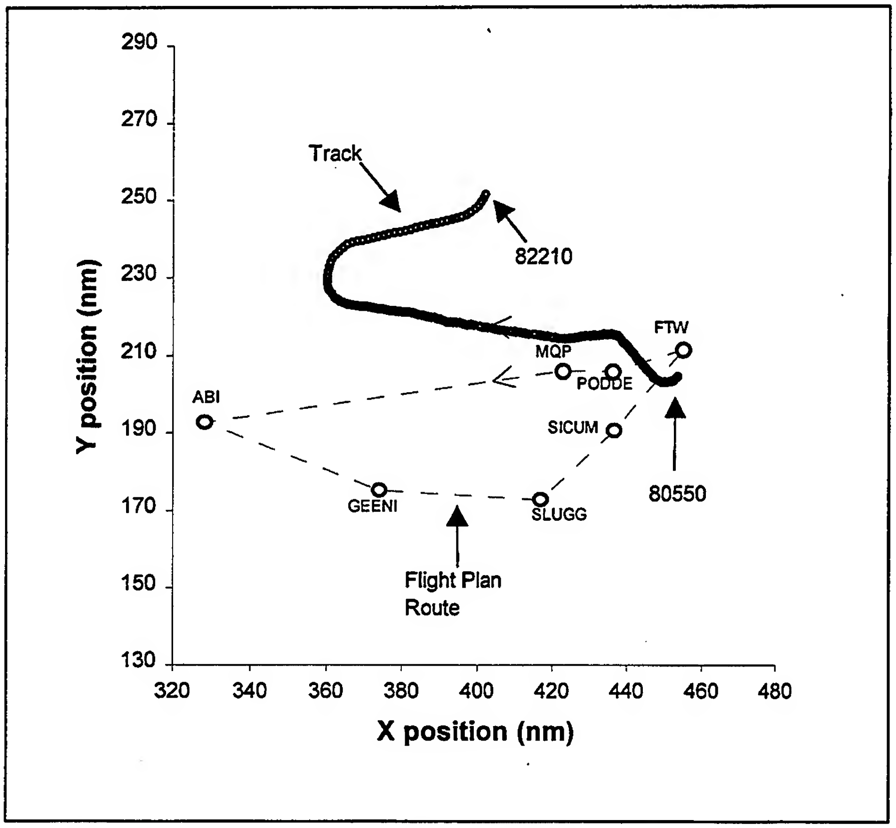


**Figure C.2-7: Interpolated Track and Route XY Position**

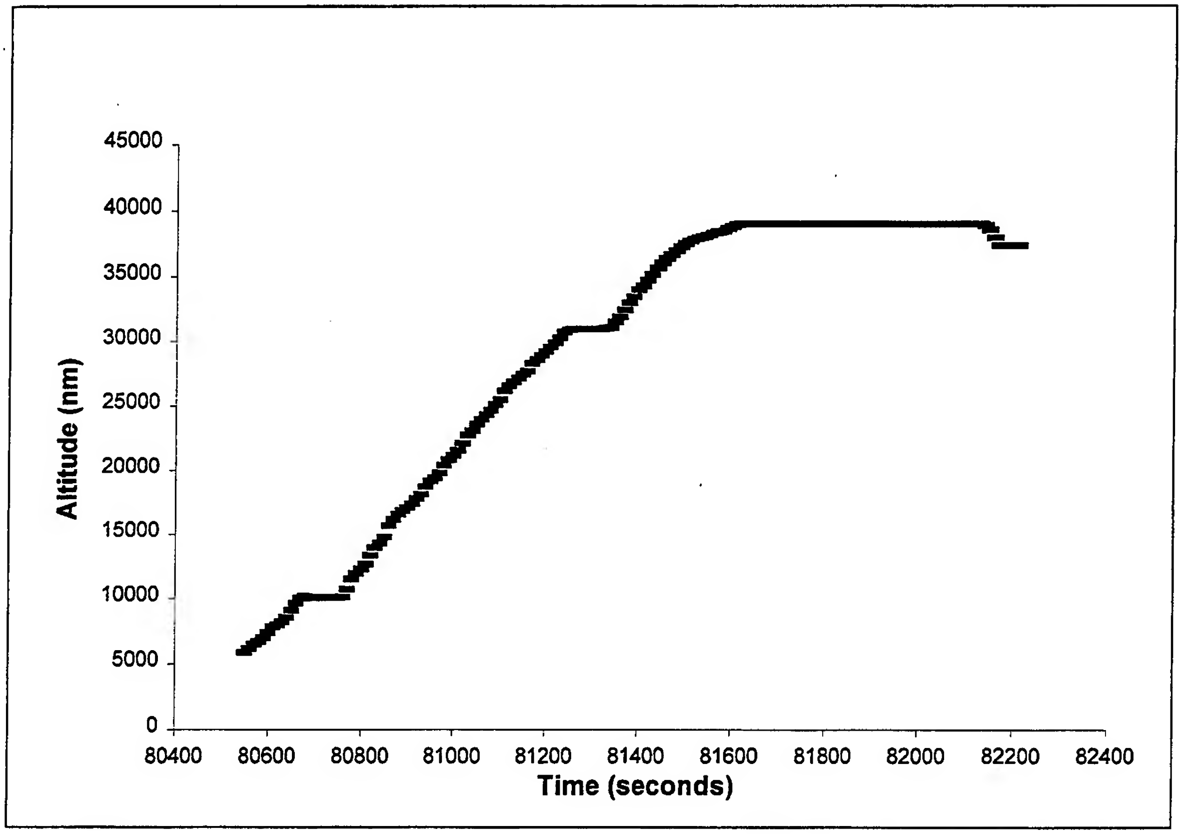


**Figure C.2-8: Interpolated Track Altitude**

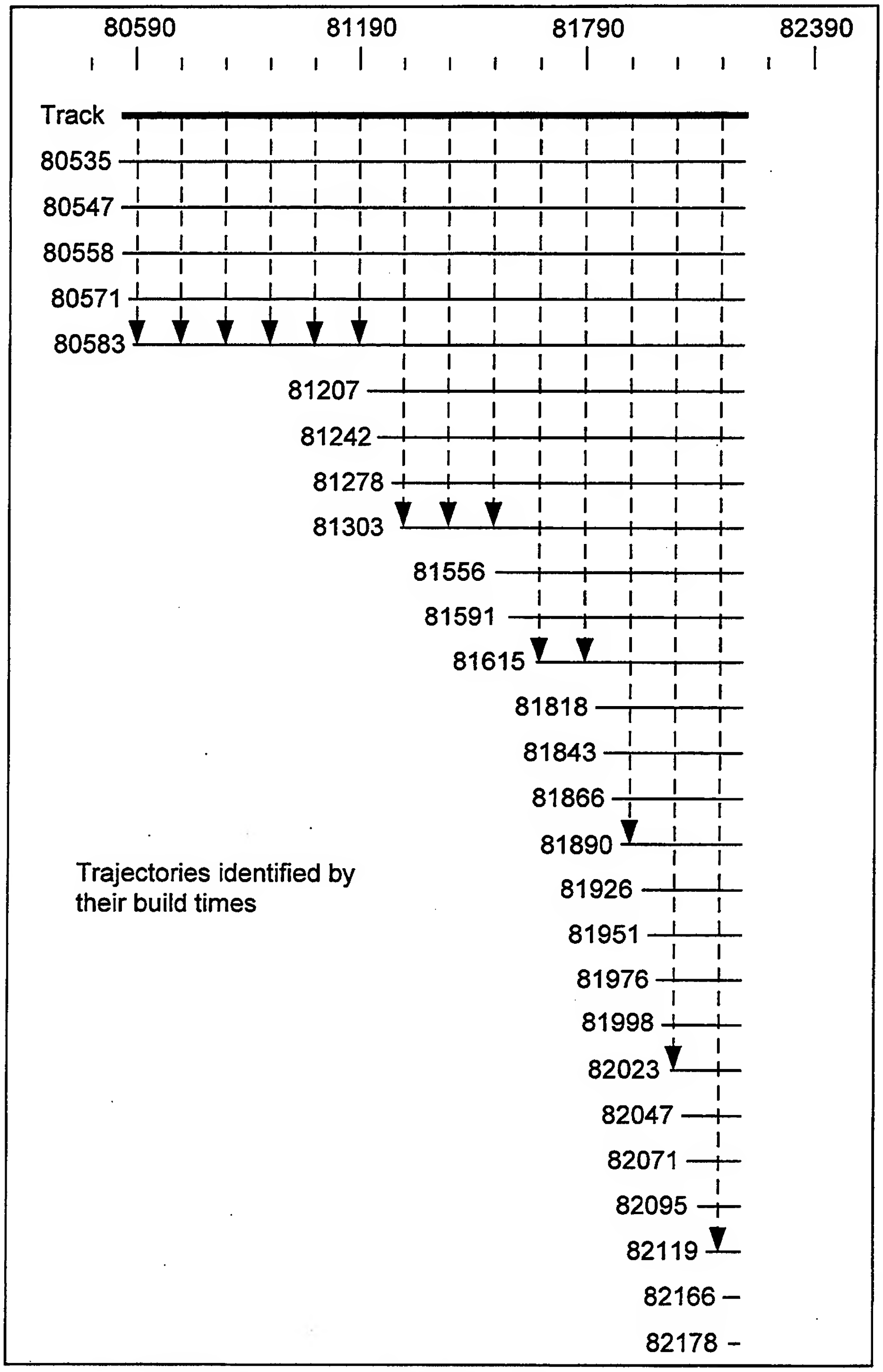


**Figure C.2-9: Sampled Trajectories**

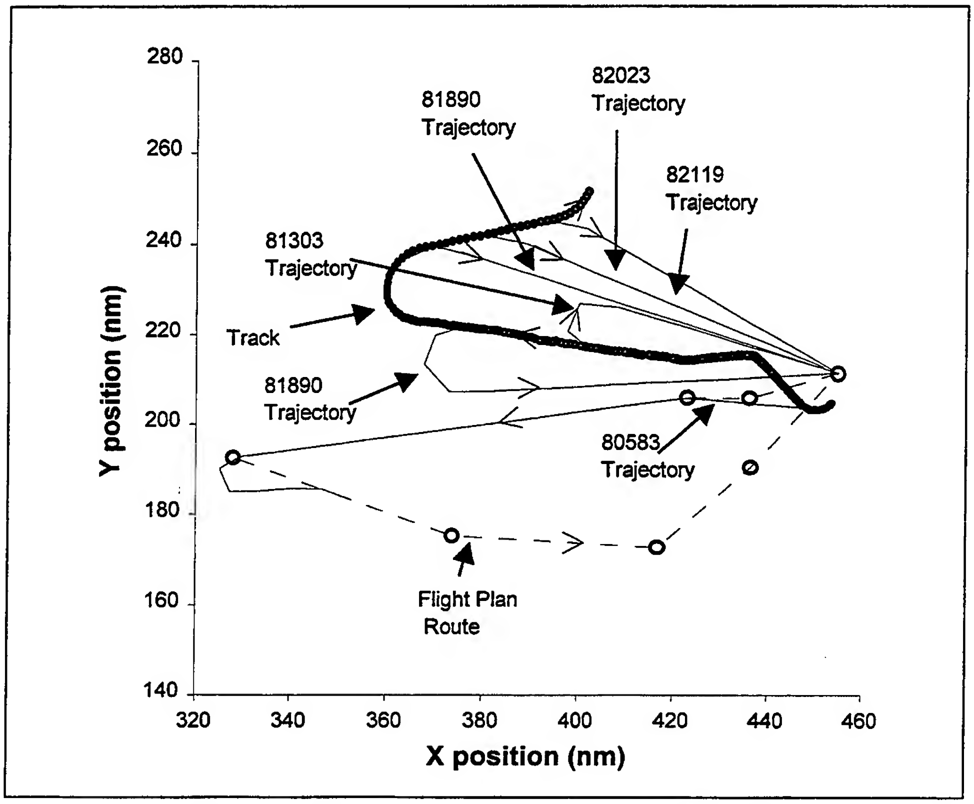


**Figure C.2-10: Track, Sampled Trajectories, and Route**

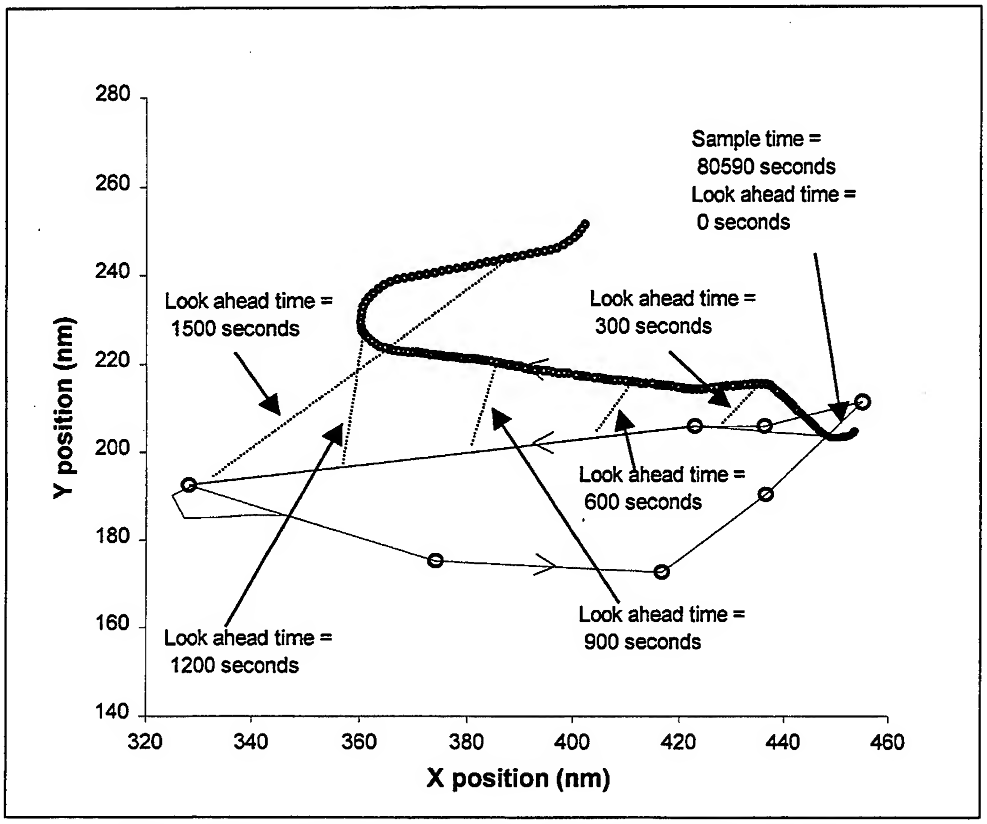


**Figure C.2-11: Sampled XY Points Along 80583 Trajectory**

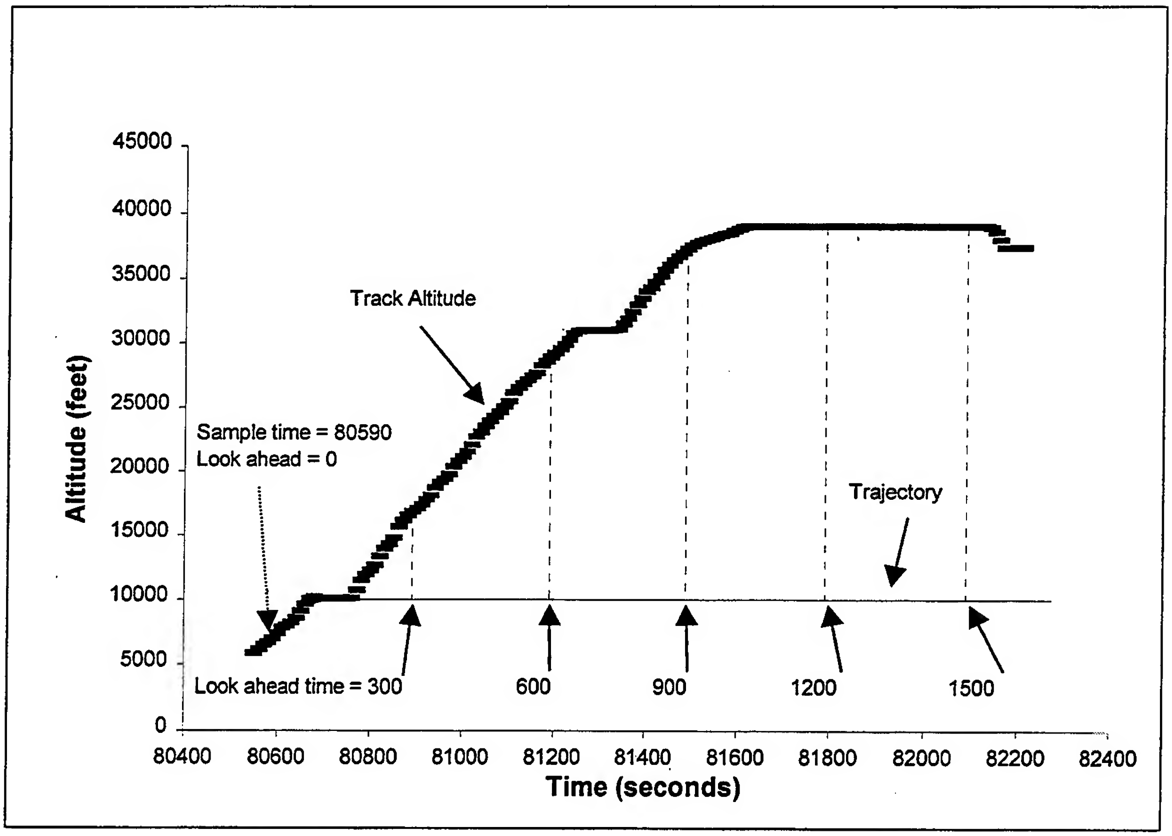


**Figure C.2-12: Sampled Altitude Points Along 80583 Trajectory**

Table C.2-4: Trajectory Metrics

| Sample Time | Traj Build Time | Look Ahead Time | Long Error | Lat Error | Vert Error |
|---|---|---|---|---|---|
| 80590 | 80583 | 0 | -0.32 | -0.04 | -74.08 |
| | | 300 | -6.88 | 10.74 | 6840.00 |
| | | 600 | -8.59 | 11.40 | 18889.00 |
| | | 900 | -7.48 | 19.31 | 27290.00 |
| | | 1200 | -7.76 | 28.44 | 28990.00 |
| | | 1500 | -61.99 | 42.67 | 28990.00 |
| 80710 | 80583 | 0 | -1.98 | 2.74 | 120.69 |
| | | 300 | -9.06 | 8.20 | 11539.00 |
| | | 600 | -8.26 | 14.24 | 20990.00 |
| | | 900 | -7.66 | 22.13 | 28940.00 |
| | | 1200 | -22.05 | 39.81 | 28990.00 |
| 80830 | 80583 | 0 | -5.31 | 8.65 | 3940.00 |
| | | 300 | -8.67 | 10.11 | 16840.00 |
| | | 600 | -7.32 | 17.55 | 25190.00 |
| | | 900 | -7.33 | 24.98 | 28990.00 |
| | | 1200 | -48.76 | 41.78 | 28990.00 |
| 80950 | 80583 | 0 | -7.07 | 9.94 | 9140.00 |
| | | 300 | -8.40 | 12.73 | 20940.00 |
| | | 600 | -7.50 | 20.95 | 28190.00 |
| | | 900 | -12.40 | 34.26 | 28990.00 |
| | | 1200 | -85.87 | 12.16 | 28590.00 |
| 81070 | 80583 | 0 | -8.52 | 8.60 | 14290.00 |
| | | 300 | -7.69 | 15.94 | 22439.00 |
| | | 600 | -7.62 | 23.64 | 28990.00 |
| | | 900 | -35.19 | 41.15 | 28990.00 |
| 81190 | 80583 | 0 | -8.59 | 11.40 | 18889.00 |
| | | 300 | -7.48 | 19.31 | 27290.00 |
| | | 600 | -7.76 | 28.44 | 28990.00 |
| | | 900 | -61.99 | 42.67 | 28990.00 |
| 81310 | 81303 | 0 | -0.32 | -0.14 | 1.08 |
| | | 300 | -43.26 | 13.70 | 17550.03 |
| 81430 | 81303 | 0 | -10.48 | 5.70 | 6732.92 |
| | | 300 | -67.20 | 15.35 | 22145.94 |
| 81550 | 81303 | 0 | -31.16 | 12.81 | 14477.60 |
| | | 300 | -87.99 | 9.03 | 26788.20 |
| 81670 | 81615 | 0 | -1.02 | 2.18 | 0.00 |
| | | 300 | -20.07 | -33.54 | 10277.69 |
| 81790 | 81615 | 0 | -19.46 | -3.27 | 3551.77 |
| | | 300 | -17.75 | -36.48 | 14393.46 |
| 81910 | 81890 | 0 | -0.17 | -0.79 | 685.23 |
| 82030 | 82023 | 0 | -0.13 | -0.37 | 242.42 |
| 82150 | 82119 | 0 | -0.81 | -1.85 | 758.92 |